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Boletaceae from Shanxi Province of northern China with descriptions of ten new species

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Abstract

The Boletaceae is a highly diverse group of organisms with both ecological and edible values. There are many studies on Boletaceae in China, but the area investigated is generally the region of sourthwestern and southern China. The knowledge of Boletaceae in northern China is limited. In this study, we surveyed the species diversity of Boletaceae in Shanxi Province, northern China. Molecular phylogenetic analyses were performed using a concatenated internal transcribed spacer of the nuc rDNA (ITS), the large subunit of nuclear ribosomal RNA gene (nrLSU), the translation elongation factor 1-α gene (*tef1*), and the second largest subunit of RNA polymerase II gene (*rpb2*) dataset (totally including 1 140 sequences from 409 collections). Our phylogenetic tree revealed 24 Boletaceae species from our collections, which are distributed in 16 genera, i.e. *Boletus*, *Butyriboletus*, *Caloboletus*, *Chalciporus*, *Cyanoboletus*, *Hemileccinum*, *Hortiboletus*, *Leccinum*, *Neoboletus*, *Retiboletus*, *Rubroboletus*, *Strobilomyces*, *Suillellus*, *Tylopilus*, *Villoboletus*, and *Xerocomus*. Of these species, 14 are identified as known species, including three new to China, and 10 are described and illustrated as new species in this paper. Accordingly, 15 species documented from Shanxi before this study are briefly discussed.

Keywords – 10 new taxa – Basidiomycetes – Boletales – ectomycorrhizal fungi – molecular analysis – taxonomy

Introduction

Boletaceae Chevall. is one of the most species-rich fungal family in basidiomycetes. Many species of this family form ectomycorrhizal symbioses with trees such as species in Pinaceae and Fagaceae (Wu et al. 2022), and some species are utilized in commercial trade for their great dietary and health value such as *Boletus edulis* Bull. and *B. meiweiniuganjun* Dentinger (Rivas-Ferreiro et al. 2023). They are therefore both ecologically and economically important and have attracted the attention of many mycologists from the early morphological stage to the current molecular stage (Snell 1941, Chiu 1948, Teng 1963, Smith & Thiers 1971, Corner 1972, Pegler & Young 1981, Singer 1986, Høiland 1987, Watling & Li 1999, Li & Song 2000, Binder & Bresinsky 2002, Dai et al. 2010, Horak 2011, Feng et al. 2012, Zhang et al. 2012, Gelardi et al. 2014a, b, c, Vizzini 2014a, b, Zhao et al. 2014a, b, Zeng et al. 2014, Orihara et al. 2016, Wu et al. 2016a, b, Zhang & Li 2018,

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Chai et al. 2019, Khmelnitsky et al. 2019, Hosen & Yang 2021, Li et al. 2021, Fu et al. 2022, Wu et al. 2022, Mao et al. 2023).

In China, the complex and diverse natural environment has resulted in high species richness of Boletaceae (Chiu 1948, 1957, Teng 1963, Bi et al. 1990, 1993, 1997, Zang et al. 2001, Li et al. 2011, 2014a, b, Zhang et al. 2012, 2014, Zeng et al. 2014, Wu et al. 2016a, b, Zhang & Li 2018, Li et al. 2021, Fu et al. 2022, Wang et al. 2022). However, the knowledge of Boletaceae is significantly insufficient in northern zone comparing to southwestern, southern and northeastern China. During the last six years, we collected a lot of specimens of Boletaceae in Shanxi Province where there are vegetation types that represent the main forests in northern China. In this study, four highly informative genetic markers (ITS, nrLSU, *tef1*, *rpb2*) are used in our molecular analyses. Morphological features and DNA-based molecular analysis were conducted based on specimens gathered, and sequences available in the GenBank database. Our aims are to: 1) clarify the species diversity of Boletaceae in Shanxi Province, northern China; 2) describe and illustrate 10 new species found in this province.

Materials & Methods

Sample collections

The collections were obtained and photographed in the field from Shanxi Province, northern China, from 2017 to 2022; then dried in a fruit drier at 40–50°C; and deposited at BJTC (Herbarium Biology Department, Capital Normal University) and HSA (Hebarium of Shanxi Institute for Functional Foods, Shanxi Agricultural University). Macroscopic characters were recorded from fresh specimens. Standardized color values matching the color of the description were taken from ColorHexa (http://www.colorhexa.com/). Microscopic characteristics were observed in sections obtained from dry specimens mounted in 5% KOH, Congo Red, or Melzer's reagent (Dring 1971). The term '[n/m/p]' means n. basidiospores from m. basidiomata of p collections. Dimensions of basidiospores are given using the following format '(a–)b–c(–d)', where the range 'b–c' represents at least 90% of the measured values, and 'a' and 'd' are the most extreme values. 'Q' refers to the length/width ratio of basidiospores in side-view; 'Q_{av}' refers to the average Q of all basidiospores ± standard deviation.

DNA extraction, PCR amplification, sequencing and nucleotide alignment

A small amount of dry basidiomata (20−30 mg) was crushed by shaking for 45 seconds at 30 Hz 2−4 times (Mixer Mill MM301, Haan, Germany) in a 1.5 mL tube, together with a 3 mm diam tungsten carbide ball. Total genomic DNA was extracted from the powdered basidiomata using NuClean Plant Genomic DNA Kit (CWBIO, Beijing, China), following the manufacturer's instructions. Fragments of four nuclear loci, including nrDNA (ITS1-5.8S-ITS2 = ITS), nuc nrLSU subunit (nrLSU), translation elongation factor 1-α (*tef1*), and RNA polymerase II second largest subunit (*rpb2*) were amplified and sequenced. The primer pairs of ITS1-F/ITS4 for ITS, LR0R/LR5 for nrLSU, EF1-B-F2/EF1-B-R for *tef1*, and RPB2-B-F2/RPB2-B-R for *rpb2* were used to amplify and sequence the above loci (Vilgalys & Hester 1990, Wu et al. 2014). PCR reactions procedures and sequencing for these loci followed the protocols described by Wu et al. (2014) and Feng et al. (2012). The PCR products were sent to Beijing Zhongkexilin Biotechnology Co. Ltd. (Beijing, China) for purifying, sequencing, and editing. Accession numbers of new and downloaded sequences stored in the NCBI database are provided in Supplementary Table 1.

Phylogenetic analyses

For this study, combined matrix of ITS-nrLSU-*tef1*-*rpb2* was compiled to identify the species and to investigate their phylogenetic position in the Boletaceae. *Suillus* aff. *luteus* and *Suillus* aff. *granulatus* were selected as outgroups based on a previous study (Wu et al. 2014). The sequences of the four loci (ITS, nrLSU, *tef1*, *rpb2*) were aligned in the online version of MAFFT 7.110 using default parameters (Katoh & Standley 2013) and manually edited in BioEdit v.7.0.9 (Hall 1999).

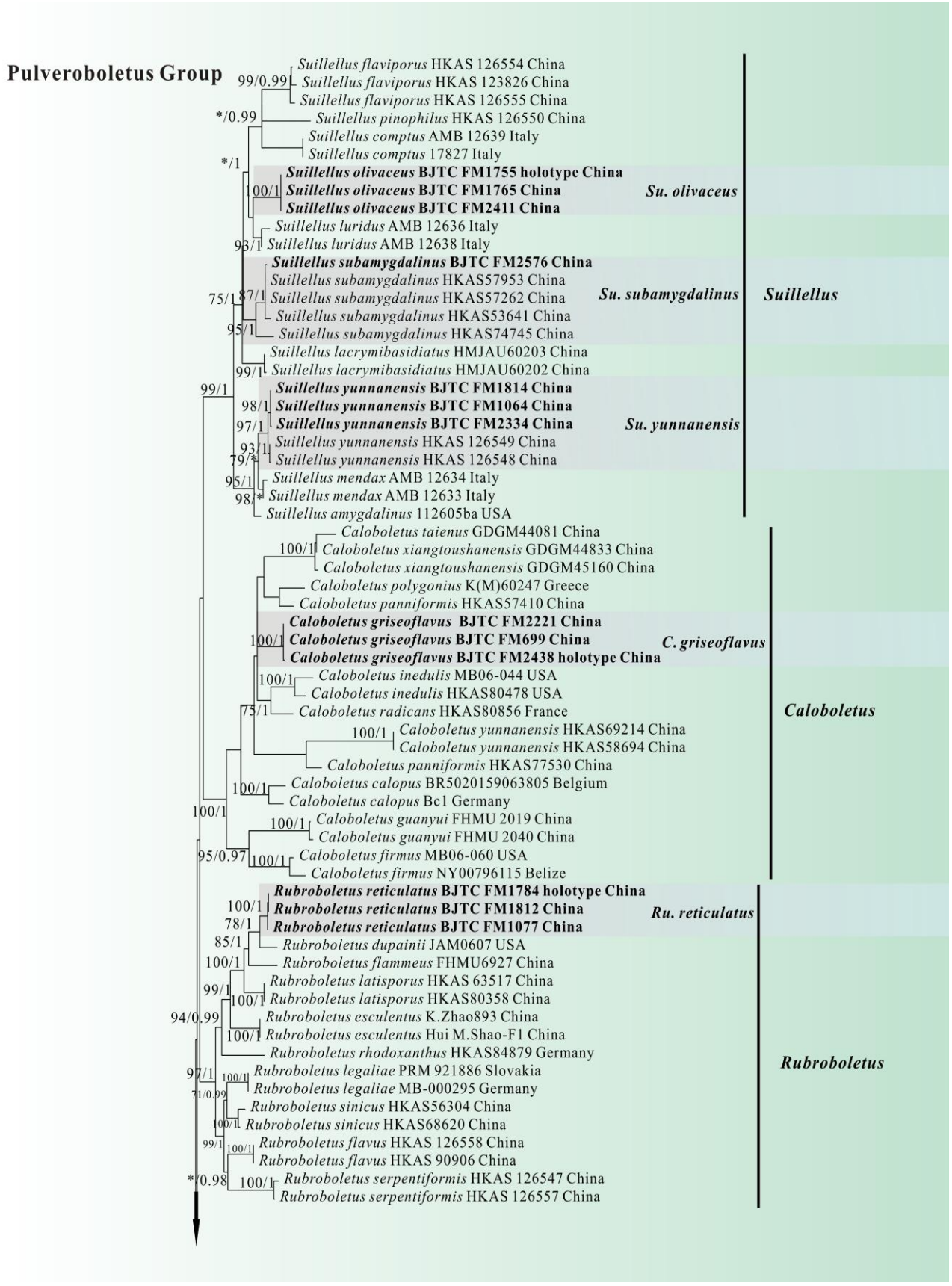
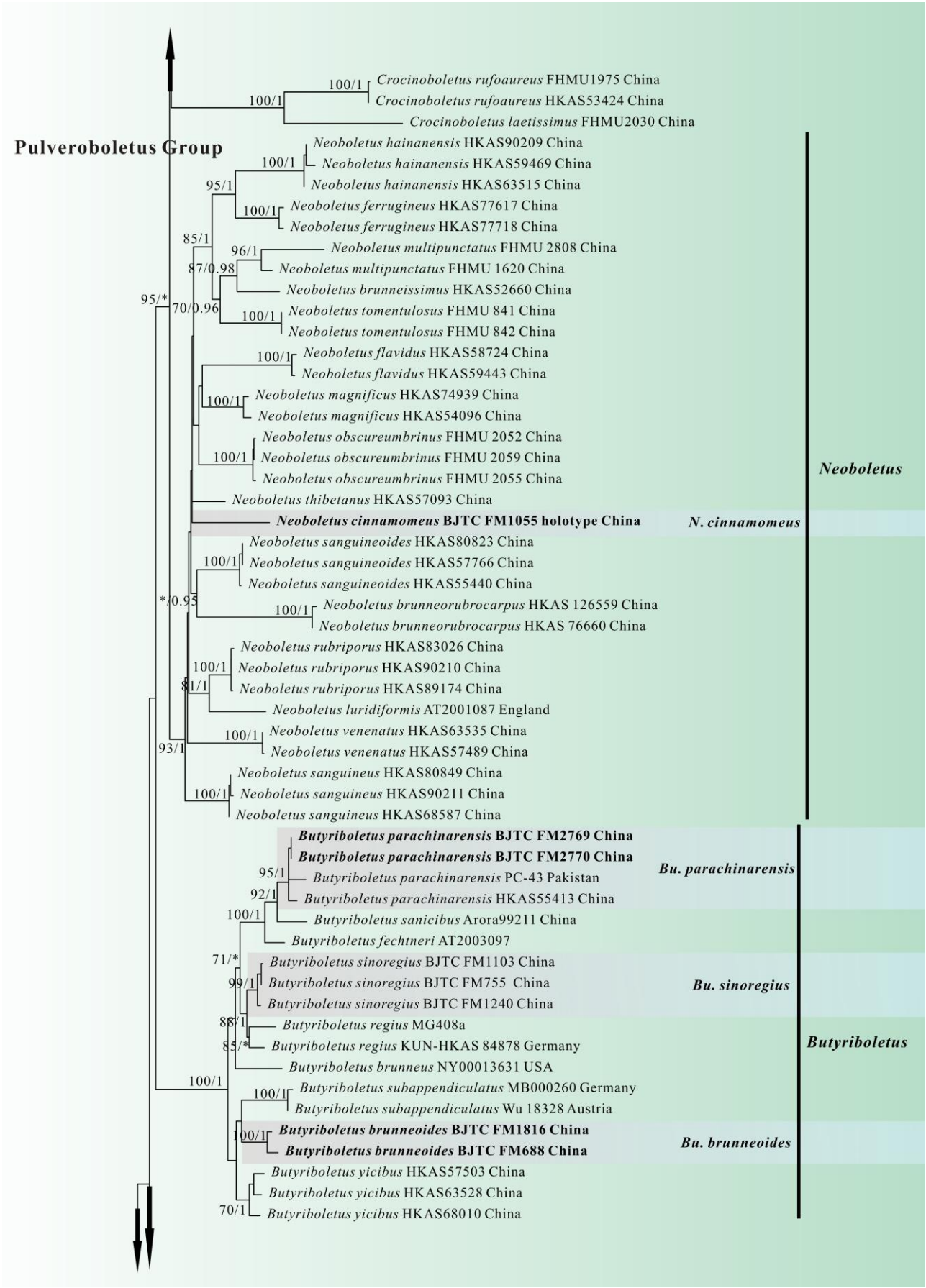


Figure 1 – Phylogenetic tree generated from a maximum likelihood analysis based on combined ITS-nrLSU-*tef1*-*rpb2* sequences, showing the phylogenetic relationships of Boletaceae. Numbers representing likelihood bootstrap support (MLBS ≥ 70%, left) and significant Bayesian posterior probability (BPP ≥ 0.95, right) are indicated above the nodes. Novel sequences are printed in bold.



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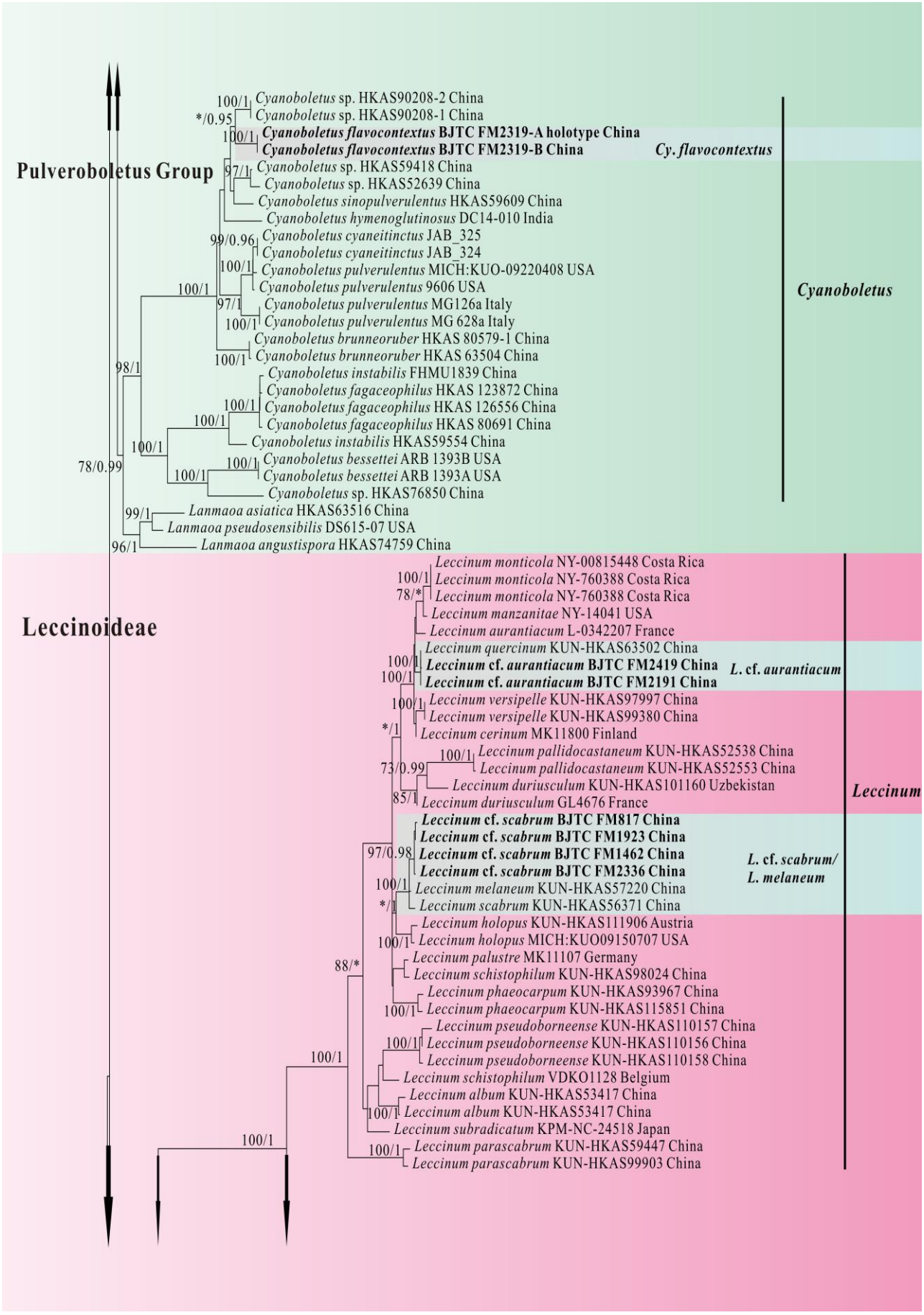
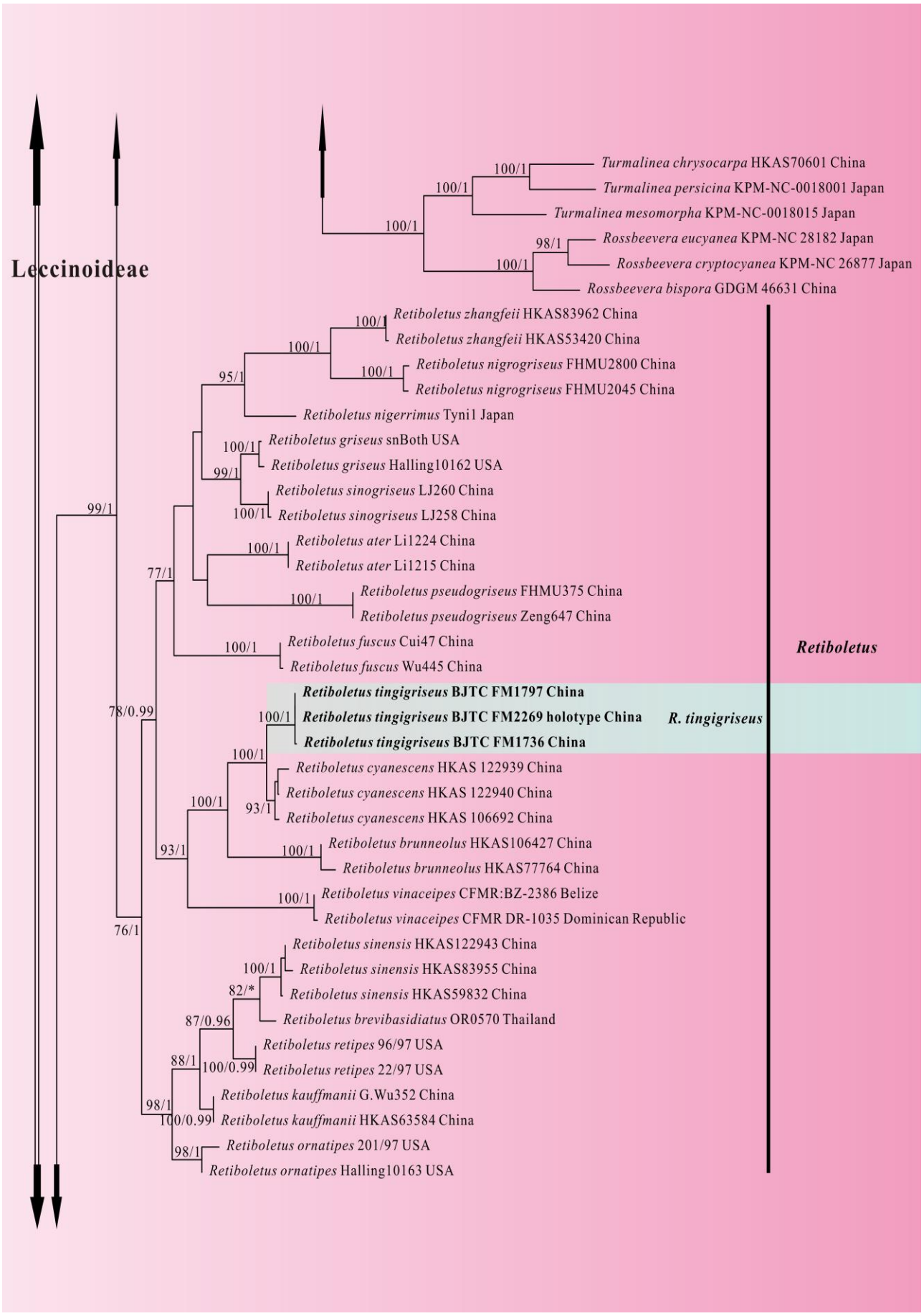


Figure 1 – Continued.



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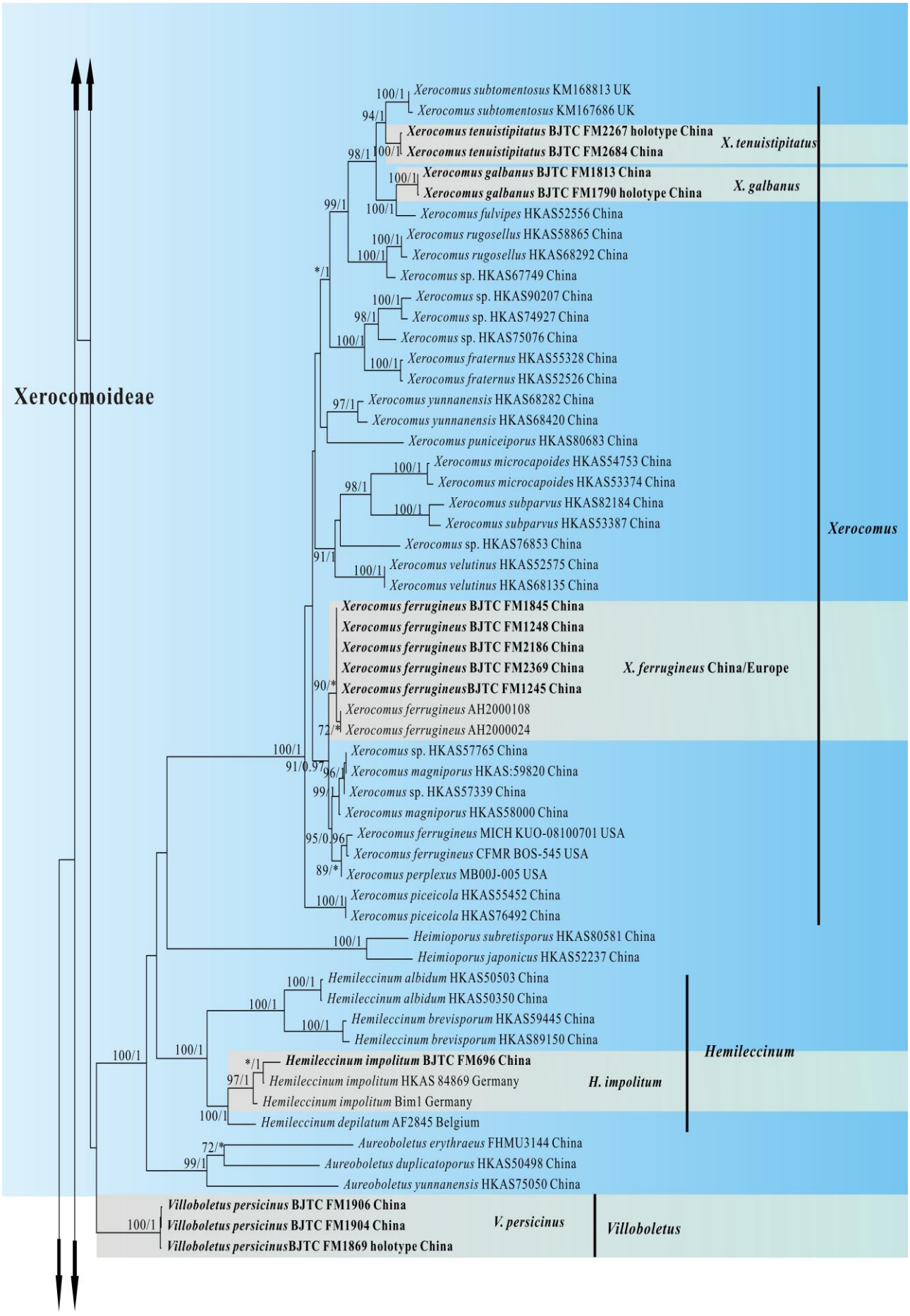

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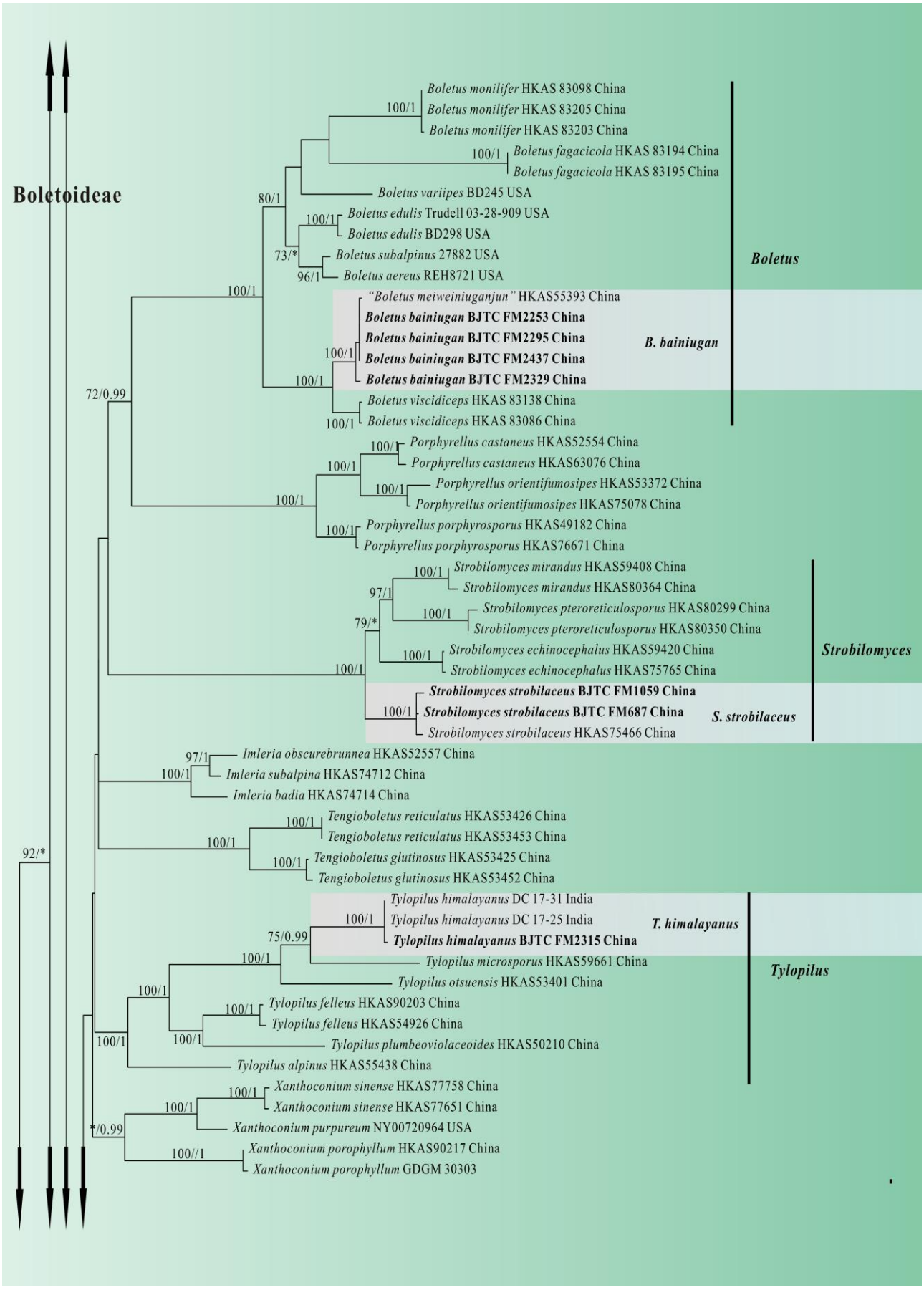

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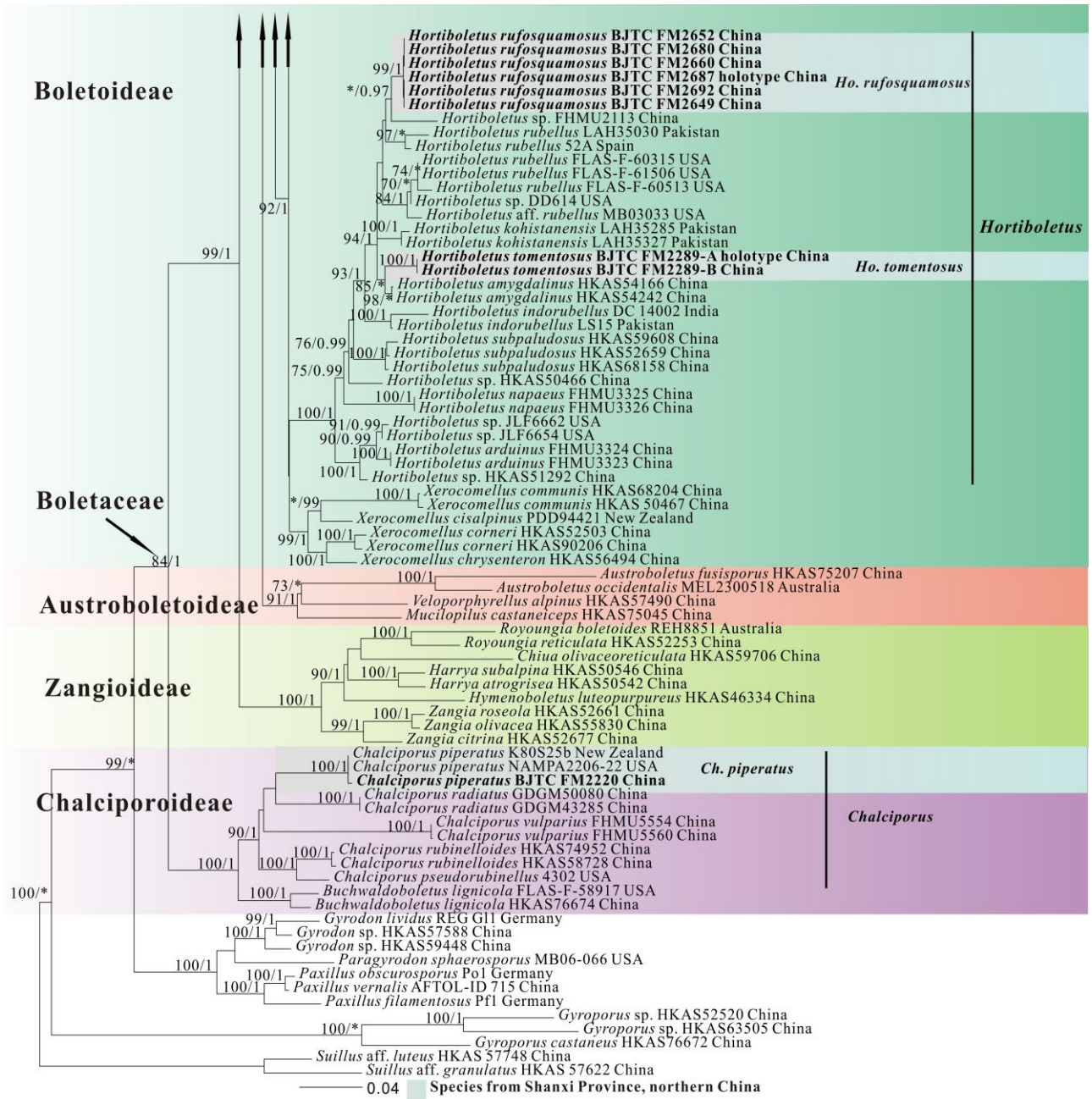

Figure 1 – Continued.

The sequences were then concatenated using SequenceMatrix 1.7.8 (Vaidya et al. 2011). To check for the degree of congruence among the different markers, single-gene analyses were conducted to assess incongruence among individual genes using the ML method (results not shown). Because no well-supported (BS>70%, Nuhn et al. 2013) conflict was detected among the topologies of the four genes, their sequences were then concatenated together for further multi-gene analyses. The final alignments were submitted to TreeBASE under accession number 30839.

Phylogenetic analyses were conducted using maximum likelihood (ML) and Bayesian inference (BI). ML analyses were carried out in RAxML 8.0.14 (Stamatakis 2014) with all parameters at default settings. As RAxML only supports the GTR model of nucleotide substitution, the GTRGAMMAI model was used for phylogenetic analyses. 1000 bootstrap replicates were computed in RAxML using a rapid bootstrap analysis and search for the best-scoring ML tree. BI analysis was performed in MrBayes 3.1.2 (Ronquist & Huelsenbeck 2003). A partitioned mixed model was used by defining the sequences of ITS, nrLSU, *tef1*, and *rpb2* as four independent partitions, and each gene was separately modeled with different parameters. The best-fitted

substitution model for each gene marker was determined through MrModeltest v2.3 (Nylander 2004) by using Akaike Information Criterion (AIC). GTR+I+G was chosen as the best model for ITS, nrLSU and *tef*1 whereas SYM+I+G was selected as the best model for *rpb2*. We used two independent runs with four Markov chains Monte Carlo (MCMC) for 10 000 000 generations under the default settings. The average standard deviations of split frequency (ASDSF) values were far lower than 0.01 at the end of the runs. Trees were sampled every 100 generations after burn-in (25% of trees were discarded as the burn-in phase of the analyses, set up well after convergence), and 50% majority-rule consensus trees were constructed.

Clades with bootstrap support (MLBS) ≥ 70% and Bayesian posterior probability (BPP) ≥ 0.95 were considered significantly supported (Hillis & Bull 1993, Alfaro et al. 2003). All phylogenetic trees were viewed with TreeView (Page 2001).

Results

Phylogenetic analyses

The final combined ITS-nrLSU-*tef1-rpb2* dataset consisted of 1140 sequences from 409 samples, including 191 sequences newly generated from our collections. The length of the aligned dataset was 2611 characters after exclusion of poorly aligned sites, with 439 characters for ITS, 846 characters for nrLSU, 620 characters for *tef1*, and 706 characters for *rpb2*. ML and BI analyses yielded similar tree topologies and only the tree inferred from the ML analysis is illustrated with strong statistical bootstrap from ML and posterior probability from BI support values shown (Fig. 1).

In the phylogenetic analyses, members of Boletaceae in the dataset formed a monophyletic lineage, and which includes seven major clades, consistent with the topology of the study by Wu et al. (2014). The sequences of our 61 collections formed 24 strong support clades, indicating they were 24 distinct species, and these species were respectively placed in 16 genera, i.e. *Boletus*, *Butyriboletus*, *Caloboletus*, *Chalciporus*, *Cyanoboletus*, *Hemileccinum*, *Hortiboletus*, *Leccinum*, *Neoboletus*, *Retiboletus*, *Rubroboletus*, *Strobilomyces*, *Suillellus*, *Tylopilus*, *Villoboletus*, and *Xerocomus*. Of them, 10 species are described as new species, and the remaining 14 clades correspond well to the previously described species including three new to China. The abbreviations of relevant genera mentioned in this work are given in Table 1.

Table 1 The currently known genera of Boletaceae in Shanxi Province of northern China and the abbreviations of generic names mentioned in this work.

Generic names	Abbreviations	Generic names	Abbreviations
Boletus	*B.*	*Neoboletus*	*N.*
Butyriboletus	*Bu.*	*Retiboletus*	*R.*
Caloboletus	*C.*	*Rubroboletus*	*Ru.*
Chalciporus	*Ch.*	*Strobilomyces*	*S.*
Cyanoboletus	*Cy.*	*Suillellus*	*Su.*
Hemileccinum	*H.*	*Tylopilus*	*T.*
Hortiboletus	*Ho.*	*Villoboletus*	*V.*
Leccinum	*L.*	*Xerocomus*	*X.*

Boletus L., Sp. pl. 2: 1176 (1753)

MycoBank number: MB 17174; Facesoffungi number: FoF 14984

Notes – *Boletus* was established by Linnaeus (1753). The genus is morphologically characterized by the surface of the immature poroid hymenophore is covered with a layer of tangled white hyphae, stipe is more or less reticulated, and the context is whitish to white, unchanging in color when exposed (Coker & Beers 1943, Smith & Thiers 1971, Corner 1972, Singer 1986, Horak 2005, Halling et al. 2014, Cui et al. 2016). There are about 350 species accepted for this genus

according to He et al. (2019). In this paper, a known species discovered from Shanxi Province of northern China is documented as follows.

Figure 2 – Fresh basidiomata of Boletaceae species. a–b *Boletus bainiugan* (BJTC FM1013, BJTC FM2329). c–d *Butyriboletus brunneoides* (BJTC FM1785, BJTC FM1816). e–f *Butyriboletus parachinarensis* (BJTC FM2769, BJTC FM2770). g–h *Butyriboletus sinoregius* (BJTC FM1103, BJTC FM1240). i–j *Caloboletus griseoflavus* (BJTC FM699, BJTC FM2221). k–l *Chalciporus piperatus* (BJTC FM2220). Scale bars: a–l = 2 cm.

Boletus bainiugan Dentinger, in Dentinger & Suz, Index Fungorum 29: 1 (2013)

Figs 2a–b, 3

MycoBank number: MB 550249; Facesoffungi number: FoF 15000

Basidiomata medium to large-sized. Pileus 37–180 mm diam; convex to broadly convex, then plane to slightly depressed center when mature; surface glabrous, even or sometimes rugose, dark brown (#b0856d) to black brown (#998f86) at first, then brown (#cdb48c) to yellow-brown (#dbc4a6); context up to 30 mm, white (#ffffff), unchanging in color when exposed. Hymenophore tubulose, depressed around apex of stipe; surface covered with white (#ffffff) hyphae at first, then turning dull yellow (#eeebc5) with age, unchanging in color when exposed; tubes concolourous with the surface of hymenophore, up to 8 mm long; pores roundish, 0.7–0.9 mm diam. Stipe 53–120 × 11–35 mm, central, cylindrical to subcylindrical, solid, enlarged downwards, pale brown (#e9ceac) to brown (#cb9f7f); surface covered with brown (#895837) reticula all over the stipe; context white (#ffffff), unchanging in color when exposed. Basal mycelium white (#ffffff). Odor and taste are not recorded.

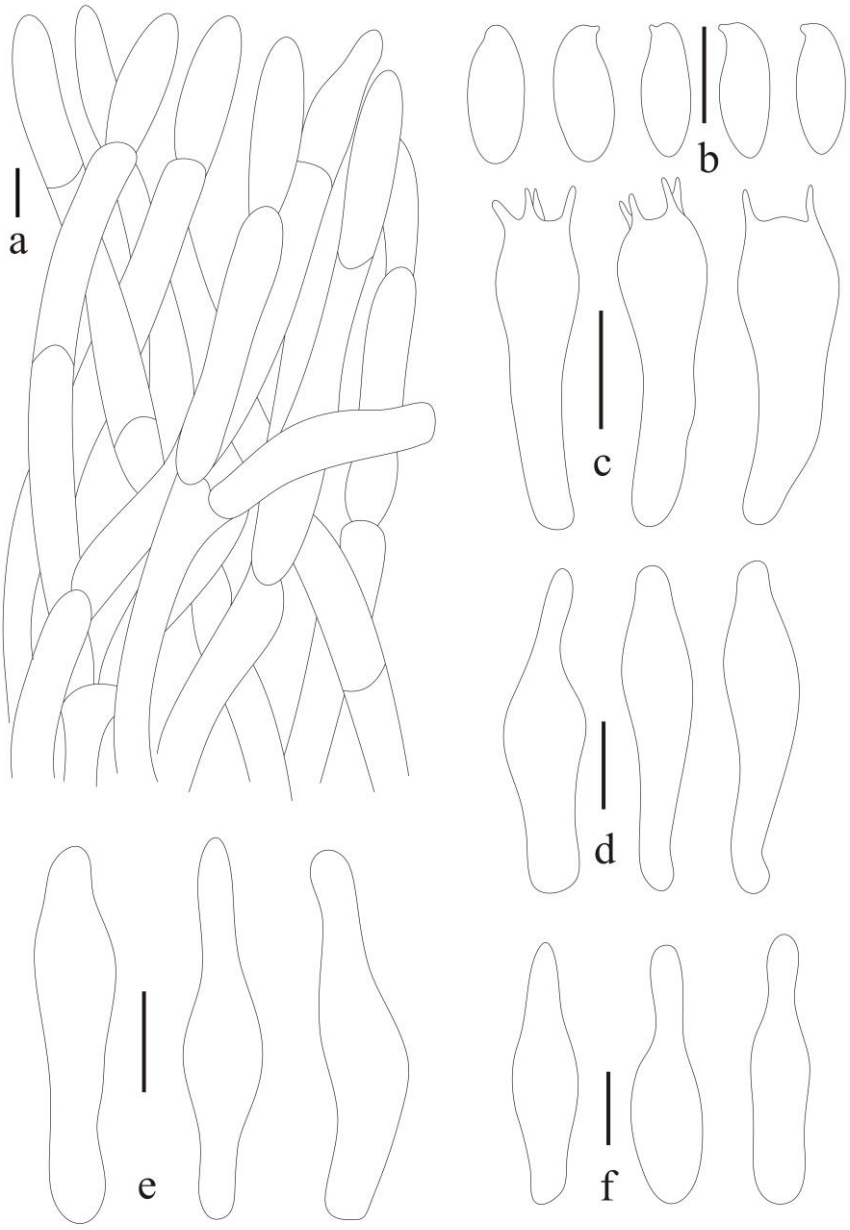

Figure 3 – *Boletus bainiugan*. a Pileipellis. b Basidiospores. c Basidia. d Cheilocystidia. e Pleurocystidia. f Caulocystidia. Scale bars: a–d = 10 μm.

Basidiospores [100/2/3] 11–15 × 4–5.5 μm, Q = 2.6–3.34, Q_{av} = 2.97 (± 0.18), subfusiform in side view, sometimes with slight suprahilar depression, elliptic-fusiform to subfusiform in face view, pale yellow in water or 5% KOH, smooth. Basidia 22–30 × 8.5–12.5 μm, clavate, 4-spored, occasionally 2-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, cylindrical hyphae, 4–13 μm wide. Cheilocystidia 25–45 × 7–11 μm, subfusiform to fusoid-ventricose. Pleurocystidia similar to cheilocystidia in shape and size. Pileipellis an interwoven trichoderm, composed of more or less vertically arranged, thin-walled, hyaline and pale brown hyphae, 4–13 μm in diam, terminal elements subcylindric to subfusiform, 10–50 × 5–13 μm. Stipitipellis a hymeniform, with caulocystidia 20–60 × 6–10 μm, clavate to lageniform, thin-walled. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in coniferous or broadleaf forest, currently only known from China.

Specimens examined – China, Shanxi Province, Jincheng City, Qinshui County, Lishan Mountains, Zhongchunlinchang, on the ground in mixed forest dominated by *Quercus* spp., 1680 m elev, 24 August 2020, H. Liu, LH1153 (BJTC FM1013); *ibid.*, on the ground in broadleaf forest dominated by *Quercus* sp., 1616.5 m elev, 10 August 2022, N. Mao, MNM583 (BJTC FM2253); *ibid.*, Shangchuan Village, on the ground in broadleaf forest dominated by *Quercus* sp., 1710.5 m elev, 11 August 2022, N. Mao, MNM607 (BJTC FM2295); Pu County, Wulu Mountain, on the ground in broad leaved forest, 1780 m elev, 13 August 2022, J.C. Lv, LJC240 (BJTC FM2329); *ibid.*, on the ground in broadleaf forest dominated by *Quercus* sp., 1498 m elev, 14 August 2022, N. Mao, MNM678 (BJTC FM2437).

Note – *Boletus bainiugan* is characterized by its brown pileus with a glabrous surface, stipe covered with brown reticula, trichodermal pileipellis and subfusiform basidiospores (Cui et al. 2016). *Boletus bainiugan* is often confused with *B. edulis* by their similar morphology with distinct reticulations of the stipe. However, *B. edulis* differs from *B. bainiugan* by its pileus with a white margin and relatively larger basidiospores (15–19 × 5–6 μm) (Alessio 1985, Cui et al. 2016). Our studies showed that *B. bainiugan* preferred the warm climate and is closely related to *Quercus* spp. in Shanxi Province, where it has a popular occurring at summer season in both the southern region of Lvliang Mts. and the eastern area of Zhongtiao Mts in Shanxi Province.

Butyriboletus D. Arora & J.L. Frank, Mycologia 106(3): 466 (2014)

MycoBank number: MB 803207; Facesoffungi number: FoF 14985

Notes – *Butyriboletus* (*Bu.*) was established to accommodate the *Boletus* sect. *Appendiculati* Estadès & Lannoy, which have reddish to reddish brown pileal surface, yellowish to yellow hymenophore, usually turning blue when exposed, and stipe surface covered with reticulations (Arora & Frank 2014, Wu et al. 2016a, Fu et al. 2022, Wang et al. 2022). A total of 11 species of *Butyriboletus* are currently recorded in southern China, i.e. *Bu. brunneoides* L. Fan & H.Y. Fu, *Bu. hainanensis* N.K. Zeng, Zhi Q. Liang & S. Jiang, *Bu. huangnianlaii* N.K. Zeng, H. Chai & Zhi Q. Liang, *Bu. pseudoroseoflavus* Yang Wang, Bo Zhang & Yu Li, *Bu. pseudospeciosus* Kuan Zhao & Zhu L. Yang, *Bu. roseoflavus* (Hai B. Li & Hai L. Wei) D. Arora & J.L. Frank, *Bu. sanicibus* D. Arora & J.L. Frank, *Bu. sinoregius* L. Fan & H.Y. Fu, *Bu. subregius* Yang Wang, Bo Zhang & Yu Li, *Bu. subsplendidus* (W.F. Chiu) Kuan Zhao, G. Wu & Zhu L. Yang, and *Bu. yicibus* D. Arora & J.L. Frank. In this paper, three known species discovered from Shanxi Province of northern China are documented as follows.

Butyriboletus brunneoides L. Fan & H.Y. Fu, in Fu, Li & Fan, Phytotaxa 544(2): 213 (2022)

Figs 2c–d, 4

MycoBank number: MB 842144; Facesoffungi number: FoF 15001

Basidiomata small to medium-sized. Pileus 35–94 mm diam; hemispherical to convex at a young age, then broadly convex with age; surface dry, yellowish brown (#ffbb78) to brown (#c96400), margin decurved; context up to 9 mm thick, solid, white (#ffffff) to pale yellow (#f2ffb8) to yellow (#fffc9a), unchanging in color when exposed. Hymenophore tubulose, adnate,

surface bright yellow (#ffff1a) to light yellow (#eaff80), turning blue when exposed; tubes concolorous with hymenophore surface, up to 8 mm long; pores somewhat elliptical or subround, 0.2–0.3 mm in diam. Stipe 45–60 × 7–30 mm, central, cylindrical, solid, equal or slightly enlarged downwards, pale yellow (#eaff80), developing pale red stains near the base; surface covered with a fine pale yellow (#eaff80) reticulum; context white (#ffffff) to pale yellow (#f2ffb8), turning blue (#53809e) when exposed. Basal mycelium whitish. Odor and taste are not recorded.

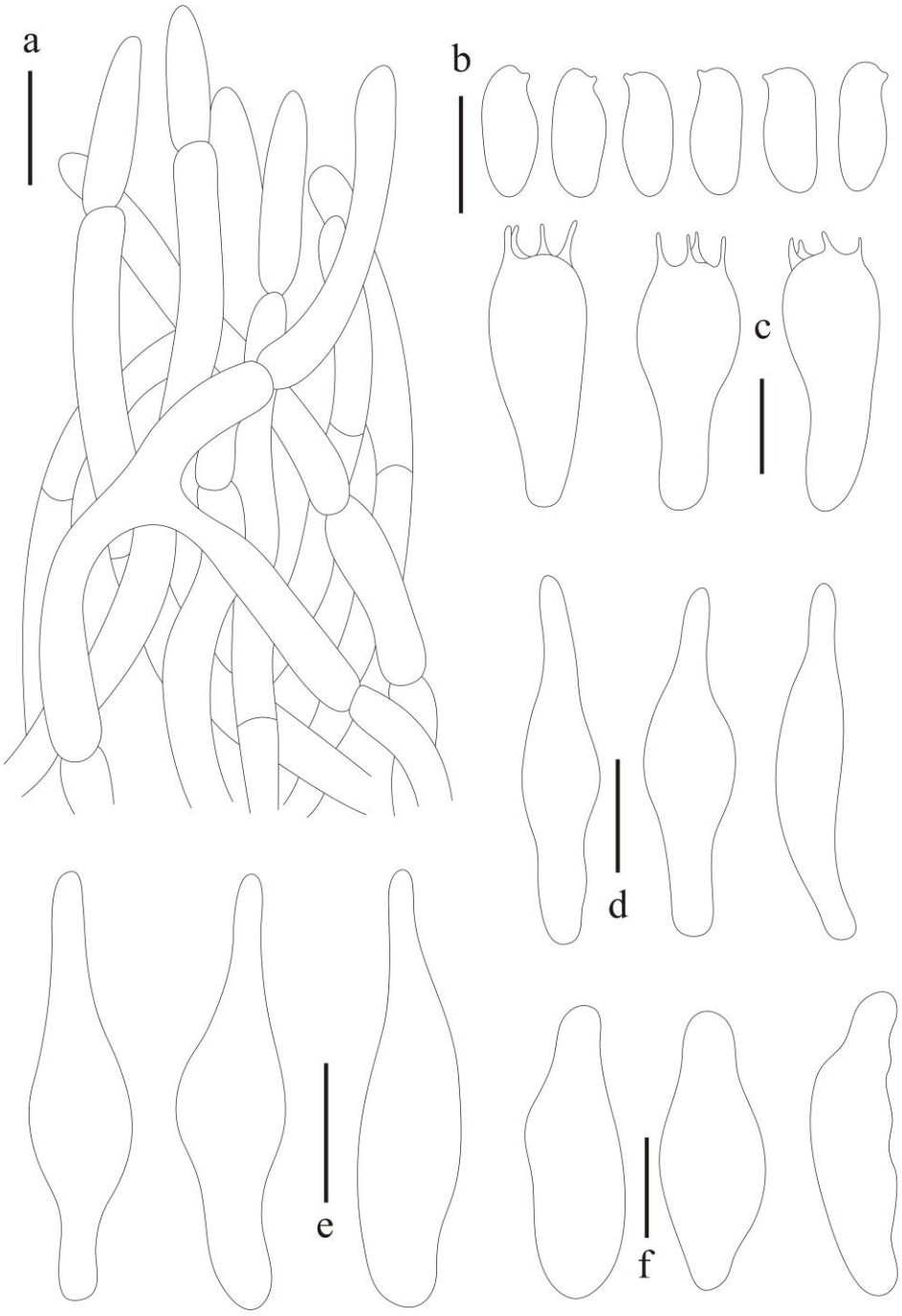

Figure 4 – *Butyriboletus brunneoides*. a Pileipellis. b Basidiospores. c Basidia. d Cheilocystidia. e Pleurocystidia. f Caulocystidia. Scale bars: a–d = 10 μm.

Basidiospores [60/2/2] 11–15(–17) × 3–5 μm, Q = 3.25–3.75(–4.33), Q_{av} = 3.5 (± 0.25), subfusiform to fusiform in side view with slight suprahilar depression, ellipsoid-fusiform to subfusiform in face view, yellowish in water or 5% KOH, smooth. Basidia 27.5–35 × 7.5–10 μm,

clavate, hyaline to yellowish in water or 5% KOH, 4-spored, occasionally 2- or 3-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 4–10 μm wide. Cheilocystidia 30–32.5 × 7.5–10 μm, fusiform or subfusiform, hyaline, thin-walled, smooth. Pleurocystidia 35–45 × 8–12.5 μm, fusiform to fusoid-ventricose, hyaline, thin-walled, smooth. Pileipellis a trichoderm, composed of interwoven hyphae 2.5–5 μm wide, smooth, thin-walled, always with pale brown to pale yellow extracellular pigments. Stipitipellis hymeniform, with caulocystidia 16–36 × 4–13 μm, lageniform. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest dominated by *Quercus* spp., currently only known from Shanxi Province, northern China.

Specimens examined – China, Shanxi Province, Qinshui County, Shangwoquan Village, on the ground in broadleaf forest dominated by *Quercus* sp., 1150 m elev, 26 July 2021, J.C. Lv, LJC045 (holotype BJTC FM1816); *ibid.*, 1170 m elev, 21 August 2019, H. Liu, LH716 (BJTC FM688); *ibid.*, 1140 m elev, 26 July 2021, N. Mao, MNM358 (BJTC FM1785).

Note – *Butyriboletus brunneoides* is rare and recently described from southern Shanxi Province. It is characterized by the yellowish brown to brown pileus, unchanging color of pileal context when exposed, stipe surface covered with pale yellow reticulum. *Butyriboletus brunneoides* is highly similar to the North America *Bu. brunneus*, the difference between them is just in the surface of pileus, it is smooth in *Bu. brunneoides*, but with finely fibrillose in *Bu. brunneus* (Peck 1890). Additionally, the stipe of *Bu. brunneus* has red stains over the bottom half, frequently and a red zone at or above the midpoint (Peck 1890).

Butyriboletus parachinarensis Naseer, Davoodian & Khalid, in Crous et al., Persoonia 46: 421 (2021) Figs 2e–f, 5

MycoBank number: MB 839366; Facesoffungi number: FoF 15002

Basidiomata small to medium-sized. Pileus 29–59 mm diam, convex to broadly, surface dry smooth, pale brown (#9c8550) to brown (#6f5b43); context pale yellow (#cccf82), unchanging in color when exposed. Hymenophore tubulose, adnate, surface bright yellow (#cccf82) at a young age, then yellow (#cdd0a4) with age, turning blue (#53809e) when exposed; tubes concolorous with hymenophore surface. Stipe 70–128 × 8–15 mm, central, cylindrical, solid, slightly enlarged downwards, bright yellow (#d5dba7) at first, then dark yellow (#d0cf95) with age; surface covered with yellow (#9a9052) to brown (#876b55) reticulum; context pale yellow (#f2ffb8), turning blue (#53809e) when exposed. Basal mycelium whitish (#ffffff). Odor and taste are not recorded.

Basidiospores [60/2/2] 10–13 × 4–5.5 μm, Q = 2.18–2.75, Q_{av} = 2.45 (± 0.19), subfusiform to fusiform in side view with slight suprahilar depression, ellipsoid-fusiform to subfusiform in face view, yellowish in water or 5% KOH, smooth. Basidia 28–46 × 9–13.5 μm, clavate, hyaline to yellowish in water or 5% KOH, 4-spored, occasionally 2- or 3-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, cylindrical hyphae, hyphae cylindrical, 4–14 μm wide. Cheilocystidia 35–49 × 7–10 μm, fusiform or subfusiform to lageniform, hyaline, thin-walled, smooth. Pleurocystidia 30–50 × 7–11 μm, similar to cheilocystidia in shape. Pileipellis a cutis, composed of interwoven hyphae 3–8 μm wide, smooth, thin-walled, always with pale brown to pale yellow extracellular pigments, terminal elements subcylindric, 10–40 × 4–8μm. Stipitipellis hymeniform, with caulocystidia 37.5–55 × 12.5–19 μm, lageniform. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest dominated by *Quercus* spp., currently known from Pakistan and northern China.

Specimens examined – China, Shanxi Province, Changzhi City, Qingyuan County, Lingkongshan Mountains, on the ground in broadleaf forest, 12 Sep. 2022, J.Z. Cao, LH1756 (BJTC FM2769); *ibid.*, J.Z. Cao, LH1757 (BJTC FM2770).

Note – *Butyriboletus parachinarensis* is known only from Pakistan. Our two specimens from central Shanxi Province matched this species (Figs 1, 2e-f). *Butyriboletus parachinarensis* is characterized by its pileus with brown tone, bright yellow to dark yellow hymenophore turning blue

quickly when exposed, stipe surface covered with brown reticulation on the over upper part, and fusoid basidiospores (Crous et al. 2021). *Butyriboletus brunneoides* is highly similar to this species in morphology, but can be separated by its longer basidiospores (10–15 × 5–5.5 μm) (Fu et al. 2022). *Butyriboletus sanicibus* is morphologically similar and phylogenetically related to *Bu. parachinarensis* as both of the two species have brown pileus and stipe surfaces covered with reticulum. However, *Bu. sanicibus* differs from *Bu. parachinarensis* by its hymenophore surface slightly greenish with age and habitats associated with coniferous forests (Arora & Frank 2014). *Butyriboletus parachinarensis* is new to China.

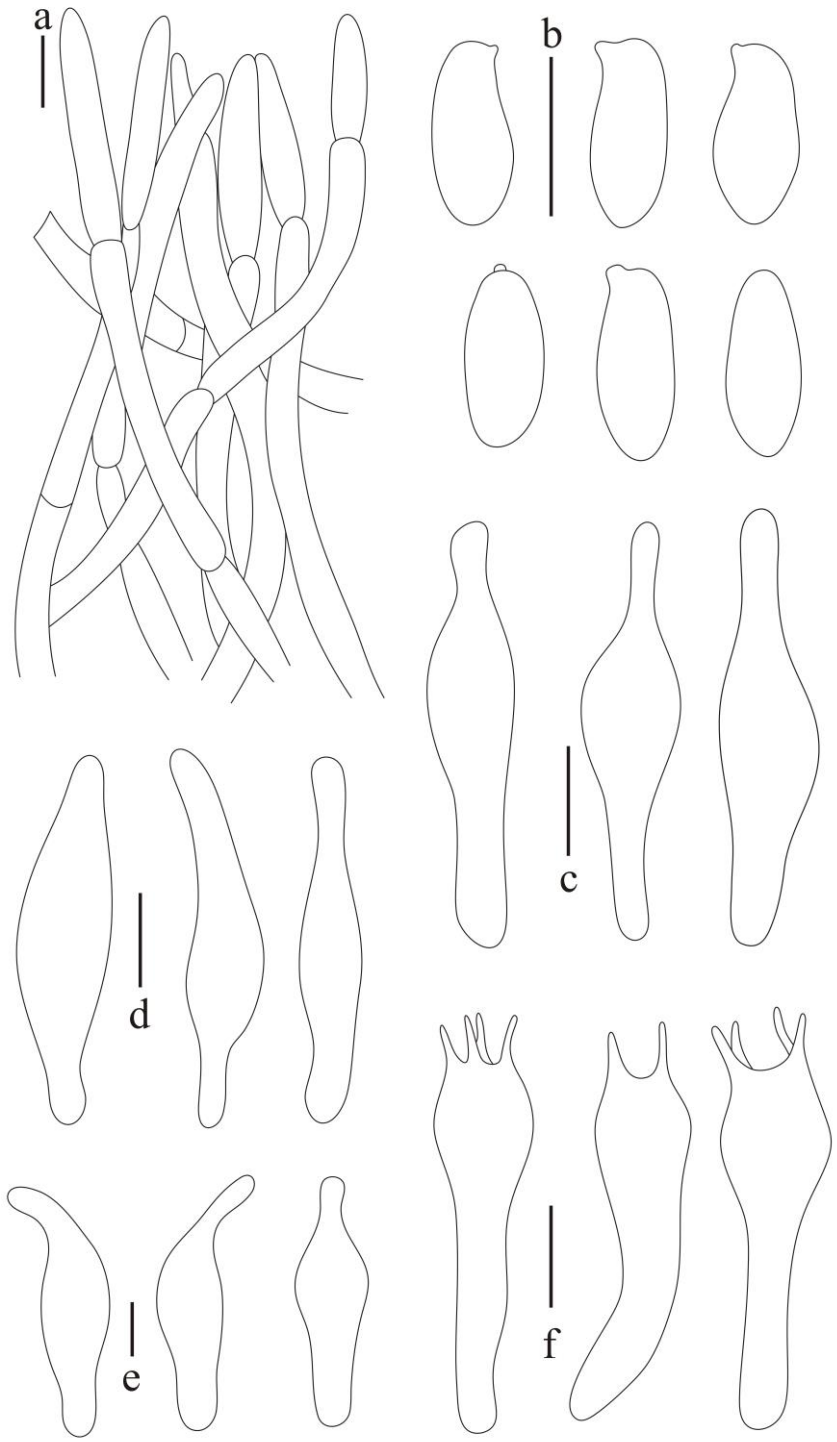

Figure 5 – *Butyriboletus parachinarensis*. a Pileipellis. b Basidiospores. c Cheilocystidia. d Pleurocystidia. e Caulocystidia. f Basidia. Scale bars: a–d = 10 μm.

Butyriboletus sinoregius L. Fan & H.Y. Fu, in Fu, Li & Fan, Phytotaxa 544(2): 215 (2022)

Figs 2g–h, 6

MycoBank number: MB 842145; Facesoffungi number: FoF 15003

Basidiomata medium-sized. Pileus 63–70 mm diam; convex at first, then broadly convex to applanate; surface dry, finely tomentose, occasionally cracking at centre, pale purple-red (#ff6b6b), and fading to pale red-orange or grayish orange (#f8f1e2) to margin; context pale yellow (#ffff4d), turning blue when exposed. Hymenophore tubulose, adnate, surface bright yellow to pale yellow at a young age, then brownish yellow with age, turning blue when exposed; tubes concolorous with hymenophore surface, 4–6 mm long; pores angular or subround, 0.3–0.7 mm diam. Stipe 52–67 × 18–23 mm diam, central, cylindrical, solid, equal, pale yellow at young, turning dark red (colour code) with age; surface covered with reticulum; context pale yellow (#f2ffb8), turning blue (#53809e) when exposed. Basal mycelium whitish. Odor and taste are not recorded.

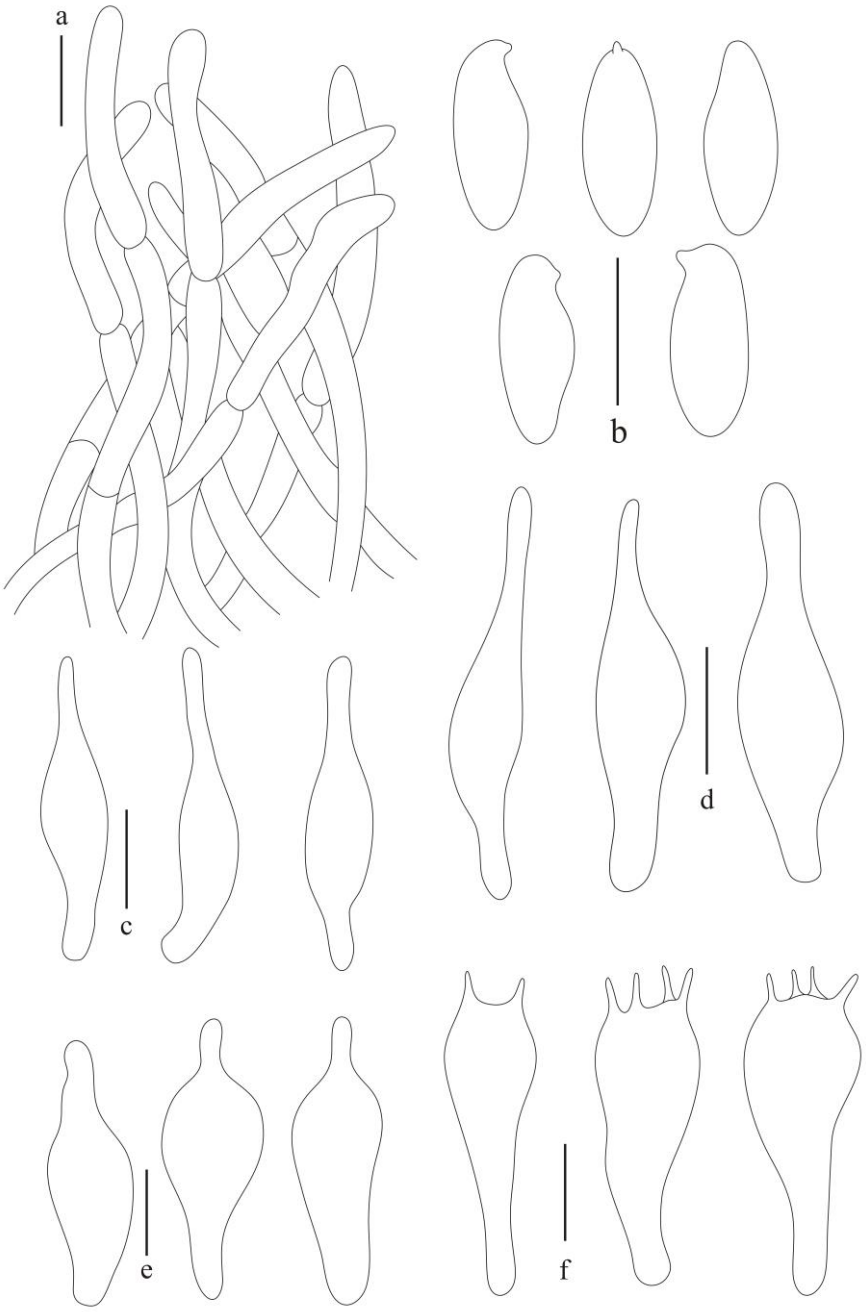

Figure 6 – *Butyriboletus sinoregius*. a Pileipellis. b Basidiospores. c Cheilocystidia. d Pleurocystidia. e Caulocystidia. f Basidia. Scale bars: a–d = 10 μm.

Basidiospores [60/2/3] 10–15 × 5–5.5 μm, Q = 2–2.68, Q_{av} = 2.34 (± 0.34), subfusiform to fusiform in side view with slight suprahilar depression, subfusiform to fusoid-ventricose in face view, yellowish in water or 5% KOH, smooth. Basidia 27.5–32.5 × 10–12.5 μm, clavate, hyaline to yellowish in water or 5% KOH, 4-spored, occasionally 2- or 3-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 4–10 μm wide. Cheilocystidia 25–42.5 × (5–)7.5–12.5(–17.5) μm, fusiform or subfusiform to lageniform with subacute apex, hyaline, thin-walled, smooth. Pleurocystidia similar to cheilocystidia in shape and size. Pileipellis a trichoderm, composed of interwoven hyphae 3–5 μm wide, smooth, thin-walled, always with pale brown to pale yellow extracellular pigments, terminal elements 15–40 × 3–7.5 μm, nearly clavate sometimes with expanding obtuse. Stipitipellis hymeniform, with caulocystidia 14–40 × 8–14 μm, subfusiform or fusiform. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest dominated by *Quercus* spp., currently only known from Shanxi Province, northern China.

Specimens examined – China, Shanxi Province, Qinshui County, Lishan Mountains, Zhongcunlinchang, on the ground in mixed forest, 1630 m elev, 22 August 2019, H. Liu, LH755 (holotype BJTC FM755); Yicheng Country, Shihelinchang, on the ground in broadleaf forest dominated by *Quercus* sp., 1960 m elev, 26 August 2020, H. Liu, LH1178 (BJTC FM1103); Qinshui County, Lishan Mountains, on the ground in mixed forest, 15 July 2020, H. Liu, LH929 (BJTC FM1240).

Note – *Butyriboletus sinoregius* is characterized by its finely tomentose pileus, and basidiomata bluing when exposed (Fu et al. 2022). This species is now only harvested from eastern Zhongtiao Mts. in southern Shanxi Province in which it is a popularly encountered boletoid mushroom and closely associated with *Quercus* spp. *Butyriboletus sinoregius* is morphologically and phylogenetically similar and related to European *Bu. regius*. Both of the two species have red tones and finely tomentose pileus, but *Bu. regius* differs from *Bu. sinoregius* by its yellow stipe with reddish tones when mature and pileal context usually not bluing when exposed (Janda et al. 2019). Additionally, after re-examing the specimens originally cited under *Bu. sinoregius* (Fu et al. 2022), we observed the presence of cheilocystidia which is similar to pleurocystidia in morphology.

Caloboletus Vizzini, Index Fungorum 146: 1 (2014).

MycoBank number: MB 550546; Facesoffungi number: FoF 14986

Notes – *Caloboletus* was established to accommodate *Boletus calopus* Pers., and its allies, which have yellow to olive yellow tubes, yellowish or reddish surface of the stipe, bluish color change when bruised, and distinctly bitter taste of the context (Hellwig et al. 2002, Vizzini 2014a, Zhao et al. 2014a, Wu et al. 2016a, Zhang et al. 2017, Chai et al. 2019). A total of five species of *Caloboletus* are currently recorded in southern China, i.e. *C. guanyui* N.K. Zeng, H. Chai & S. Jiang, *C. panniformis* (Taneyama & Har. Takah.) Vizzini, *C. taienus* (W.F. Chiu) Ming Zhang & T.H. Li, *C. xiangtoushanensis* Ming Zhang, T.H. Li & X.J. Zhong, and *C. yunnanensis* Kuan Zhao & Zhu L. Yang (Zhao et al. 2014a, Wu et al. 2016a, Zhang et al. 2017, Chai et al. 2019). The following new species is only known from northern China.

Caloboletus griseoflavus L. Fan, N. Mao & T.Y. Zhao, sp. nov. Figs 2i–j, 7

MycoBank number: MB 850260; Facesoffungi number: FoF 15004

Etymology – ***griseoflavus***, refers to the color of the grey pileus and yellow stipe.

Typification – China, Shanxi Province, Pu County, Wulu Mountain, on the ground in broadleaf forest dominated by *Quercus* sp., 1497 m elev, 14 August 2022, N. Mao, MNM679 (holotype BJTC FM2438). GenBank: ITS = OR655145, nrLSU = OR655181; *tef1* = OR659982; *rpb2* = OR659933.

Basidiomata small to medium-sized. Pileus 30–75 mm diam; subhemispherical to convex at a young age, then broadly convex to applanate; surface dry, grey white (#f8fbfd) to greish (#d0e1e7) at a young age, then greyish brown (#d4cea8) with age, finely pubescent; context up to 12 mm

thick, solid, white (#ffffff) to pale yellow (#f2ffb8), turning blue (#53809e) when exposed. Hymenophore tubulose, sinuate to adnate, surface bright yellow (#f8f3a1) at a young age, then orange-yellow (#b78c53) with age, turning blue (#53809e) when bruised; tubes concolorous with hymenophore surface; pores angular or subround, up to 0.5 mm diam. Stipe 26–60 × 8–20 mm, central, cylindrical to subcylindrical, solid, bright yellow (#f8f3a1) at a young age, then yellowish brown (#cdaf5d) with age; surface covered with yellowish brown (#cdaf5d) reticulations that gradually longitudinal towards the base; context white (#ffffff) to pale yellow (#f2ffb8), turning blue (#53809e) quickly when exposed. Basal mycelium whitish. Odor and taste are not recorded.

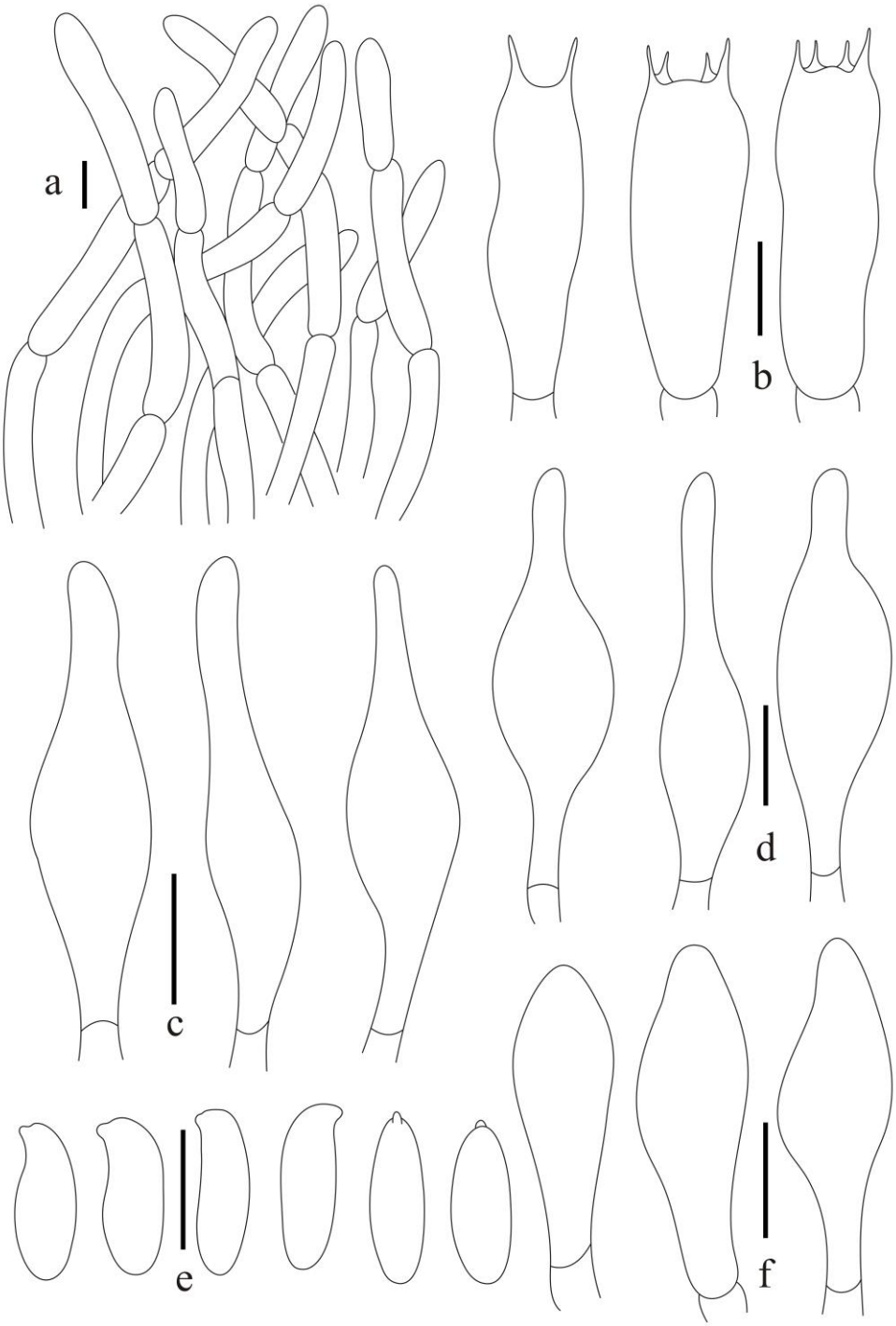

Figure 7 – *Caloboletus griseoflavus*. a Pileipellis. b Basidia. c Pleurocystidia. d Cheilocystidia. e Basidiospores. f Caulocystidia. Scale bars: a–f = 10 μm.

Basidiospores [60/3/3] 12–15(–16) × 4.5–5.5(–6) μm, Q = (2.18–)2.4–2.8(–3), Q_{av} = 2.6 (± 0.2), subfusiform to fusiform in side view with slight suprahilar depression, ellipsoid-fusiform to subfusiform in face view, slightly thick-walled (up to 0.5 μm), yellowish brown in water or 5% KOH, smooth. Basidia (30–)32–36(–40) × (7–)9–11(–13) μm, clavate, hyaline to yellowish in water or 5% KOH, 4-spored, occasionally 2- or 3-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 4–7.5 μm wide. Cheilocystidia 42–53 × 9–11 μm, fusiform or subfusiform, hyaline, thin-walled, smooth, without encrustation. Pleurocystidia 35–50 × 8–10 μm, subfusiform to fusoid-ventricose, hyaline, thin-walled, smooth, without encrustation. Pileipellis a trichoderm, composed of interwoven hyphae 4–8 μm wide, smooth, thin-walled, always with pale brown to pale yellow extracellular pigments, terminal elements 10–42 × 4–9 μm, nearly clavate sometimes with expanding obtuse. Stipitipellis hymeniform, with caulocystidia 27–43 × 8–10.5 μm, ellipsoid-fusiform or clavate, covered with pale yellow to pale brown extracellular pigments in water or 5% KOH. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest dominated by *Quercus* spp., currently only known from Shanxi Province, northern China.

Other specimens examined – China, Shanxi Province, Qinshui County, Shangwoquan Village, on the ground in broadleaf forest dominated by *Quercus* sp., 1170 m elev, 21 August 2019, H. Liu, LH728 (BJTC FM699); *ibid.*, Zhongcunlinchang, on the ground in coniferous and broad-leaved mixed forest dominated by *Quercus* sp., 1590 m elev, 10 August 2022, J.C. Lv, LJC184 (BJTC FM2221).

Note – *Caloboletus griseoflavus* is characterized by its grey white to greish pileus, yellow stipe covered with yellowish brown longitudinal reticulations. Morphologically, *C. griseoflavus* is highly similar to the European *C. radicans* (Pers.) Vizzini, however, *C. radicans* has large-sized of basidiomta (pileus 8–30 cm in diam) and a root-like base into the soil, that separate them apart (Bon et al. 1987). Of the *Caloboletus* species found in China; *C. guanyui* can be distinguished from *C. griseoflavus* by its stipe densely covered with pale-brown, brown to reddish-brown squamules (Chai et al. 2019); *C. panniformis* by its pileus covered with tomentose to velvety squamules and rose red to purplish red stipe (Wu et al. 2016a); *C. taienus* by its pale red stipe context and relatively smaller basidiospores (8–10.5 ×4–4.5 μm) (Zhang et al. 2017); *C. xiangtoushanensis* by its dull red to brownish orange pileus and brown to reddish brown stipe context (Zhang et al. 2017); and *C. yunnanensis* by its pink to reddish pileal context and purplish upper part of stipe (Zhao et al. 2014a).

Chalciporus Bataille, Bull. Soc. Hist. nat. Doubs 15: 39 (1908)

MycoBank number: MB 17277; Facesoffungi number: FoF 14987

Notes – *Chalciporus* (*Ch.*) was established to accommodate *Boletus piperatus* Bull. and its allies, which have small basidioma with a pinkish red to reddish brown hymenophore, no-ornamental stipe, smooth basidiospores, an intricate trichoderm to interwoven matted-down pileipellis (Halling et al. 2004, Wu et al. 2016a, Xu et al. 2021). A total of seven species of *Chalciporus* are currently recorded in China, i.e. *Ch. citrinoaurantius* Ming Zhang & T.H. Li, *Ch. hainanensis* Ming Zhang & T.H. Li, *Ch. piperatus* (Bull.) Bataille, *Ch. radiatus* Ming Zhang & T.H. Li, *Ch. rubinelloides* G. Wu & Zhu L. Yang, *Ch. vulparius* N.K. Zeng, Chang Xu & Zhi Q. Liang and *Ch. sinensis* N.K. Zeng, Chang Xu & Zhi Q. Liang. In this paper, a known species discovered from Shanxi Province of northern China is documented as follows.

Chalciporus piperatus (Bull.) Bataille, Bull. Soc. Hist. nat. Doubs 15: 39 (1908)

Figs 2k–l, 8

MycoBank number: MB 311021; Facesoffungi number: FoF 15005

Basidioma small-sized. Pileus 29 mm diam., applanate; surface dry, yellowish brown (#e7ae6a) to reddish brown (#d18964); context up to 11 mm thick, solid, white (#ffffff), turning pink (#ffd5c0) when exposed. Hymenophore tubulose, adnate, surface reddish brown (#cd6f3a),

turning dark rusty brown (#876562) when exposed; tubes concolorous with hymenophore surface, up to 5 mm long; pores angular or subround. Stipe 26 × 10 mm, central, cylindrical, solid, equal, reddish brown (#da7e3b); surface smooth; context brighter yellow (#ffdc7c), unchanging in color when exposed. Basal mycelium bright to dull yellow (#ffd16e). Odor and taste are not recorded.

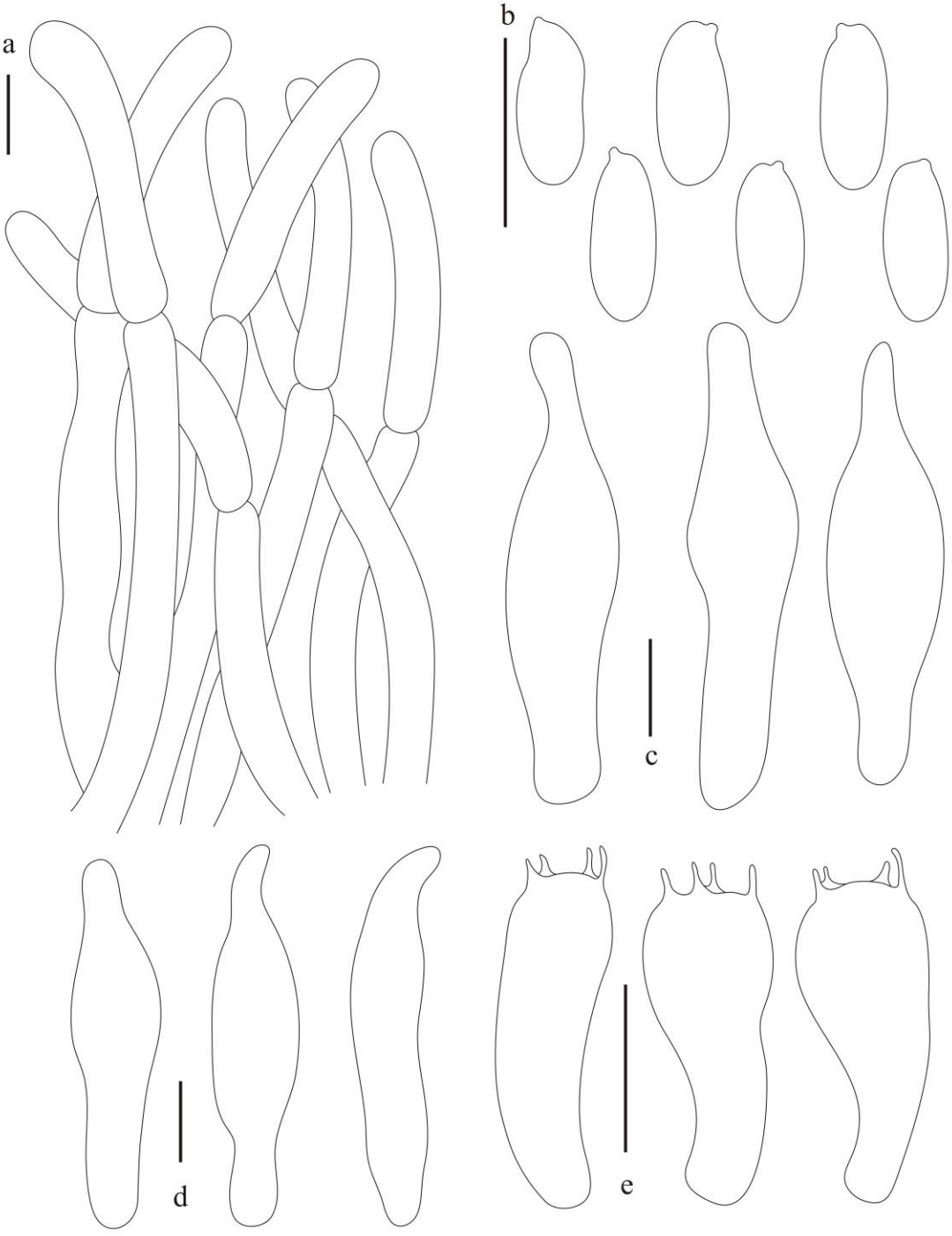

Figure 8 – *Chalciporus piperatus*. a Pileipellis. b Basidiospores. c Cheilocystidia. d Pleurocystidia. e Basidia. Scale bars: a–d = 10 μm.

Basidiospores [30/1/1] 9–11 × 3–3.5 μm, Q = 2.71–3.33, Q_{av} = 3.05 (± 0.24), subfusoid with slight suprahilar depression, yellowish in water or 5% KOH, smooth. Basidia 18–26 × 6–8 μm, clavate, hyaline to yellowish in water or 5% KOH, 4-spored, occasionally 2- or 3-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely

arranged lateral strata, hyphae cylindrical, 4–8.5 μm wide. Cheilocystidia 48–66 × 8–12 μm, fusiform or subfusiform, hyaline, thin-walled, smooth. Pleurocystidia 45–65 × 7–12 μm, similar to cheilocystidia in shape. Pileipellis a trichoderm, composed of interwoven hyphae 4–10 μm wide, smooth, thin-walled, always with pale brown to pale yellow extracellular pigments, terminal elements 15–45 × 5–12 μm, nearly clavate sometimes with expanding obtuse. Stipitipellis a trichoderm-like structure, composed of hyphae 4–8 μm in diam, terminal elements 10–40 × 4–9 μm, clavate, pale yellow in KOH. Clamp connections are absent.

Ecology and habitat – Solitary on the ground in coniferous forest or coniferous and broad-leaved mixed forest, currently known in China, Europe and North America (Halling et al. 2004, Xu et al. 2021).

Specimens examined – China, Shanxi Province, Qinshui County, Zhongcunlinchang, on the ground in mixed forest, 1590 m elev., 10 August 2022, J.C. Lv, LJC183 (BJTC FM2220).

Note – *Chalciporus piperatus* is characterized by its yellowish brown to reddish brown pileus, pileal context turning pink when exposed, reddish brown hymenophore surface turning dark rusty brown when exposed. *Chalciporus vulparius*, a species recently introduced from Hainan Province, southern China, is somewhat similar to *Ch. piperatus* in reddish brown pileus and brown stipe. However, *Ch. vulparius* is different in pileal context unchanging in color when exposed, and white basal mycelium (Xu et al. 2021). *Chalciporus rubinelloides* is also morphologically similar to *Ch. piperatus*. However, *Ch. rubinelloides* differs from *Ch. piperatus* in its grayish red to red hymenophore and relatively larger basidiospores (11.5–15 × 4–5.5 μm) (Wu et al. 2016a). *Chalciporus piperatus* is rare in Shanxi Province.

Cyanoboletus Gelardi, Vizzini & Simonini, Index Fungorum 176: 1 (2014).

MycoBank number: MB 550672; Facesoffungi number: FoF 14988

Notes – *Cyanoboletus* (*Cy.*) was established to accommodate *Boletus pulverulentus* Opat. and its allies. The genus is morphologically characterized by its yellowish brown, brown to dark brown pileus, quickly bluing context and hymenophore when exposed, and ixosubcutis to subcutis pileipellis (Gelardi et al. 2013, Wu et al. 2016a, Farid et al. 2021), and nine species are accepted according to Index Fungorum. Currently, four *Cyanoboletus* species are recorded in China, i.e. *Cy. brunneoruber* G. Wu & Zhu L. Yang, *Cy. fagaceophilus* G. Wu, Hai J. Li & Zhu L. Yang, *Cy. instabilis* (W.F. Chiu) G. Wu & Zhu L. Yang, and *Cy. sinopulverulentus* (Gelardi & Vizzini) Gelardi, Vizzini & Simonini (Gelardi et al. 2013, Wu et al. 2016a, 2023). The following new species is the fifth found in China.

Cyanoboletus flavocontextus L. Fan, N. Mao & T.Y. Zhao, sp. nov. Figs 9a, 10

MycoBank number: MB 850261; Facesoffungi number: FoF 15006

Etymology – ***flavocontextus***, refers to the color of the context.

Typification – China, Shanxi Province, Yuncheng City, Xia County, Sijiao Town, on the ground in broadleaf forest dominated by *Quercus* sp., 965.8 m elev, 12 August 2022, N. Mao, MNM615-A (holotype BJTC FM2319-A). GenBank: ITS = OR655149; nrLSU = OR655185; *tef1* = OR659986; *rpb2* = OR659937.

Basidiomata small to medium-sized. Pileus 26–60 mm diam; subhemispherical to convex at a young age, then broadly convex, brown (#b48764); surface glabrous to subtomentose, always viscid when wet; context up to 11 mm thick, solid, pale yellow (#f4e462), turning dark blue (#737c85) when exposed. Hymenophore tubulose, adnate, surface bright yellow (#f4e05f) at a young age, then orange-yellow (#d3ca5f) with age, turning blue (#737c85) quickly when exposed; tubes concolorous with hymenophore surface, 4–9 mm long; pores angular or subround, 1–2 mm diam. Stipe 40–60 × 4–12 mm, central, cylindrical to subcylindrical, solid, equal or slightly enlarged downwards; surface glabrous, yellow (#f3d36e) to yellow-brown (#efa655) at first, then gradually brown (#8e6150) towards the base, staining dark blue (#737c85) quickly when exposed; context bright yellow (#f4e05f), turning orange-yellow (#fec365) from bottom up with age and black blue (#737c85) when exposed. Basal mycelium whitish. Odor and taste are not recorded.

Figure 9 – Fresh basidiomata of Boletaceae species. a *Cyanoboletus flavocontextus* (BJTC FM2319-A). b *Hemileccinum impolitum* (BJTC FM696). c *Hortiboletus tomentosus* (BJTC FM2289-A). d–e *Hortiboletus rufosquamosus* (BJTC FM2290, BJTC FM2652). f–h *Leccinum* cf. *aurantiacum* (BJTC FM2191, BJTC FM1927, BJTC FM2742). i–l *Leccinum* cf. *scabrum* (BJTC FM2119, BJTC FM2601, BJTC FM2667, BJTC FM2721). Scale bars: a–l = 2 cm.

Basidiospores [60/2/2] (11.5–)12–13.5(–14.5) × 4.5–5.5(–6) µm, Q = 2.18–2.89(–3), Q_{av} = 2.53 (± 0.24), subfusiform to ellipsoid-fusiform in side view with slight suprahilar depression, subfusoid in face view, slightly thick-walled (to 0.5 µm), yellowish brown in water or 5% KOH, smooth. Basidia (29–)31–36(–39) × (9–)11–13 µm, clavate, 4-spored, occasionally 2-spored,

sterigmata 5–7 μm long. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 4–7 μm wide. Cheilocystidia 39–53 × 8–11 μm, fusoid-ventricose to clavate, often containing brownish intracellular pigments. Pleurocystidia 35–55 × 8–12 μm, similar to cheilocystidia in shape. Pileipellis an ixosubcutis up to 165 μm thick, composed of interwoven hyphae 5–8 μm wide, always with pale brown to pale yellow extracellular pigments, with terminal cells 30–60 × 4–7 μm, subcylindrical to cylindrical. Stipitipellis slightly gelatinized, composed of 3–7 μm wide cylindrical to filamentous hyphae, colorless, pale yellow, or pale brown in water or 5% KOH, terminal cells 12–41 × 4–6 μm, subcylindrical. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest dominated by *Quercus* sp., currently only known from Shanxi province, northern China.

Other specimens examined – China, Shanxi Province, Yuncheng City, Xia County, Sijiao Town, on the ground in broadleaf forest dominated by *Quercus* sp., 965.8 m elev, 12 August 2022, N. Mao, MNM615-B (BJTC FM2319-B).

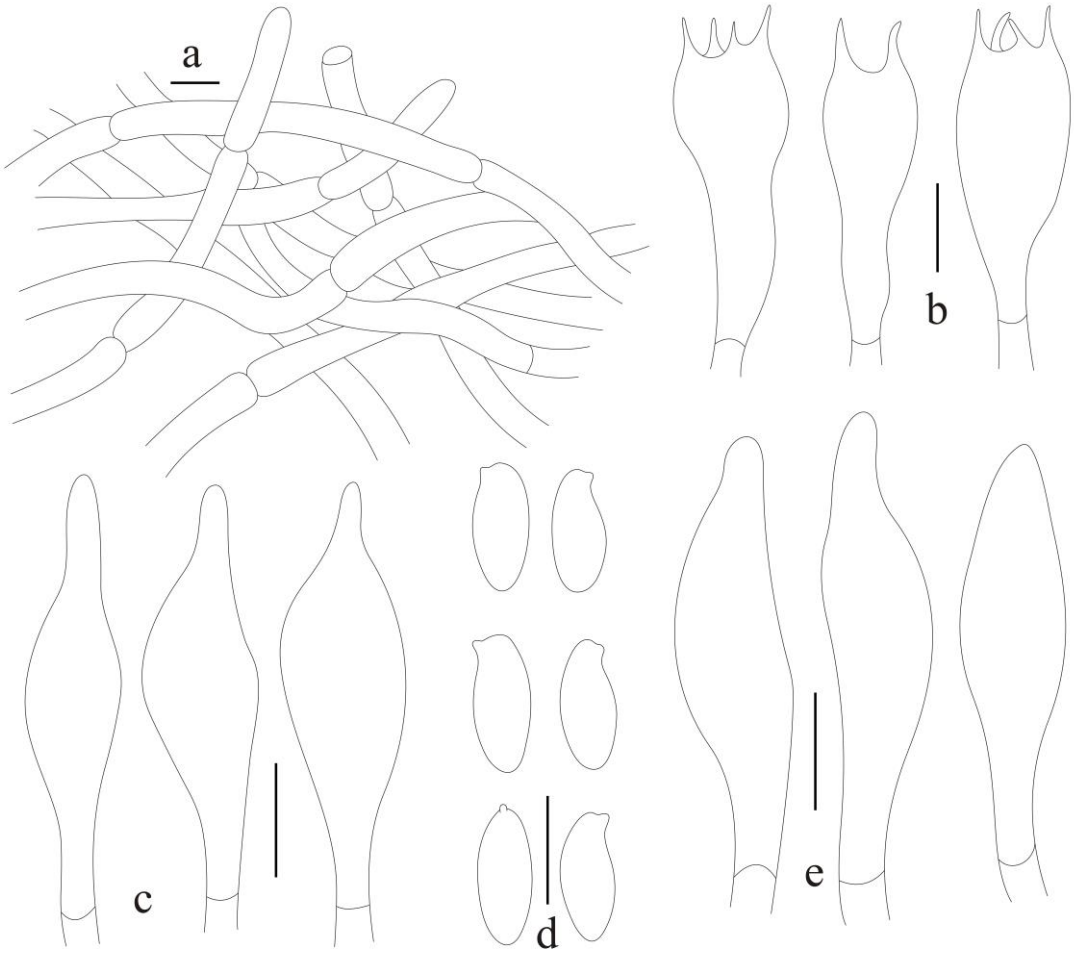

Figure 10 – *Cyanoboletus flavocontextus.* a Pileipellis. b Basidia. c Cheilocystidia. d Basidiospores. e Pleurocystidia. Scale bars: a–d = 10 μm.

Note – *Cyanoboletus flavocontextus* is characterized by its brown pileus with yellow context, glabrous stipe with bright yellow context, and ixosubcutis pileipellis. *Cyanoboletus sinopulverulentus*, a species recently described from Shaanxi Province of northwestern China (Gelardi et al. 2013), is morphologically and phylogenetically closely related to the new species. Both all are bolete with reddish brown stipe, yellow tubes, and ixosubcutis pileipellis. However, the former can be distinguished by its white context of pileus and the evenly dark brown color on both

pileus and stipe (Gelardi et al. 2013, Wu et al. 2016a). *Cyanoboletus cyaneitinctus* (Murrill) A. Farid, A.R. Franck & J.A. Bolin recently described from USA is phylogenetically related to *Cy. flavocontextus*. However, it is easily distinguished from the new species by its predominately yellow stipe (Farid et al. 2021). In addition, these two species are currently geographically separated from each other. *Cyanoboletus cyaneitinctus* occurs in eastern North America; *Cy. flavocontextus* is found in northern China.

Hemileccinum Šutara, Czech Mycol. 60(1): 52 (2008)

MycoBank number: MB 511891; Facesoffungi number: FoF 14989

Notes – *Hemileccinum* was established to accommodate *Boletus impolitus* Fr. and its allies, which have yellow hymenophore, epithelium to trichodermium pileipellis with broad hyphae, and irregularly warted and pinholed basidiospores under SEM. (Šutara 2008, Wu et al. 2016a, Li et al. 2021). There are about 15 names retained in Index Fungorum, six of which are recorded in China, i.e. *H. abidum Mei Xiang Li, Zhu L. Yang & G. Wu, H. brevisporum* Mei Xiang Li, Zhu L. Yang & G. Wu, *H. ferrugineipes* Mei Xiang Li, Zhu L. Yang & G. Wu, *H. parvum* Mei Xiang Li, Zhu L. Yang & G. Wu, *H. rugosum* G. Wu & Zhu L. Yang, and *H. indecorum* G. Wu & Zhu L. Yang. In this paper, a known species discovered from Shanxi Province of northern China is documented as follows.

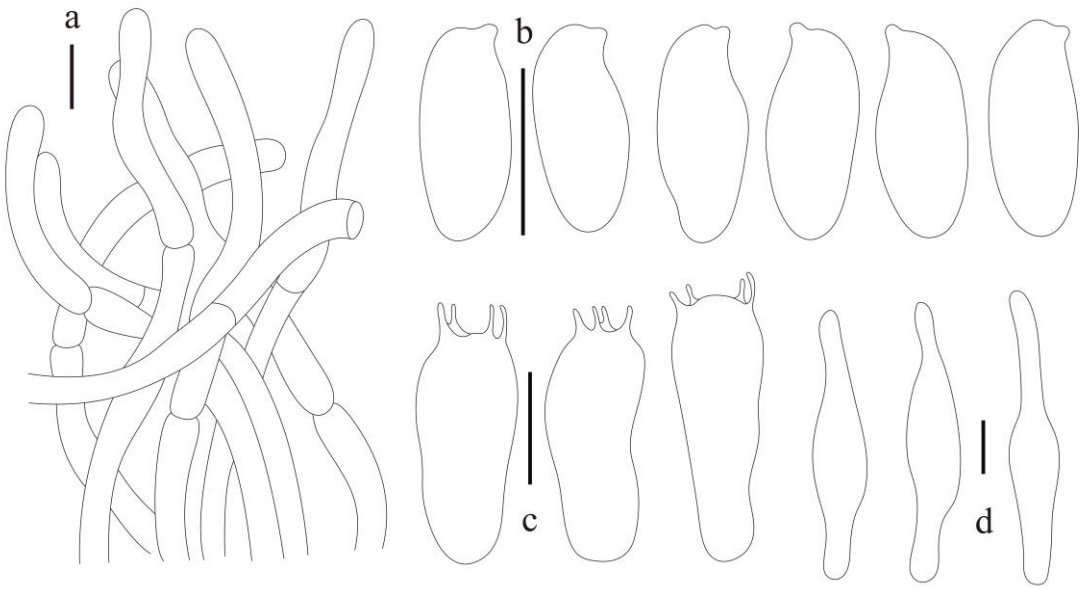

Figure 11 – *Hemileccinum impolitum*. a Pileipellis. b Basidiospores. c Basidia. d Pleurocystidia. Scale bars: a–d = 10 μm.

Hemileccinum impolitum (Fr.) Šutara, Czech Mycol. 60(1): 55 (2008) Figs 9b, 11

MycoBank number: MB 511902; Facesoffungi number: FoF 15007

Basidioma medium-sized. Pileus 65 mm diam, applanate, margin slightly uplifted, greyish brown (#e2c34d); context pale yellow (#ffff86), unchanging in color when exposed. Hymenophore tubulose, depressed around the apex of stipe; surface lemon yellow (#ffff86), unchanging in color when exposed; tubes concolourous with the surface of hymenophore; pores roundish. Stipe 38 × 18 mm, central, cylindrical to subcylindrical, solid, narrowing at the base, cream (#f5fdd2) to pale yellow (#fbfdbc), lemon yellow at the apex, context pale yellow (#ffff86), unchanging in color when exposed. Basal mycelium white (#ffffff). Odor and taste are not recorded.

Basidiospores [30/1/1] 12–15 × 5–6 μm, Q = 2.16–2.72, Q_{av} = 2.5 (± 0.15), fusiform to fusiform-ellipsoid, sometimes with slight suprahilar depression, pale yellow in water or 5% KOH, smooth under light microscopy. Basidia 23–30 × 9–10 μm, clavate, 4-spored, occasionally 2-spored. Hymenophoral trama nearly phylloporoid type that is divergent, with distinct mediostratum

and densely arranged lateral strata, hyphae cylindrical, 3–8 μm wide. Cheilocystidia not observed. Pleurocystidia sparse, 50–65× 8–12 μm, smooth, thin-walled, lageniform. Pileipellis an interwoven trichoderm, composed of more or less vertically arranged thin-walled, hyaline or pale brown hyphae 3–7 μm in diam, terminal cells 13–37 × 3–6 μm, cylindrical. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in Coniferous or broadleaf forest, currently only known from China.

Specimens examined – China, Shanxi Province, Jincheng City, Qinshui County, Shangwoquan village, on the ground in broad leaved forest, 1170 m elev, 21 August 2019, H. Liu, LH724 (BJTC FM696)

Note – *Hemileccinum impolitum* is characterized by its basidiomata unchanging in color when exposed, greyish brown pileus, habitat associated with broadleaf forests. A collection from Shanxi Province matched this species (Fig. 1). This species is new to China and rare. Our material does not differ significantly morphologically from the European material. *Hemileccinum depilatum* (Redeuilh) Šutara is similar to *H. impolitum*. However, *H. depilatum* differs from *H. impolitum* by its wrinkled or hammered pileus and palisadoderm pileipellis (Šutara 2008).

Hortiboletus Simonini, Vizzini & Gelardi, Index Fungorum 244: 1 (2015)

MycoBank number: MB 551213; Facesoffungi number: FoF 14990

Notes – *Hortiboletus* (*Ho.*) was established to accommodate *Boletus rubellus* Krombh. and its allies. The genus is morphologically characterized by its pileus with wine-red tinge, yellow–brown to red-brown stipe, and palisadoderm pileipellis (Gelardi 2009, Vizzini 2015, Wu et al. 2016a), and 12 species are accepted in Index Fungorum. Five species are currently recorded in China, i.e. *Ho. amygdalinus* Xue T. Zhu & Zhu L. Yang, *Ho. arduinus* N.K. Zeng, H.J. Xie & W.F. Lin, *Ho. napaeus* N.K. Zeng, H.J. Xie, S. Jiang & Zhi Q. Liang, *Ho. rubellus* (Krombh.) Simonini, Vizzini & Gelardi, and *Ho. subpaludosus* (W.F. Chiu) Xue T. Zhu & Zhu L. Yang (Li & Song 2003, Wu et al. 2016a, Xie et al. 2020). In this paper, two new species discovered from Shanxi Province of northern China are described as follows.

Hortiboletus rufosquamosus L. Fan, N. Mao & T.Y. Zhao, sp. nov. Figs 9d–e, 12

MycoBank number: MB 850262; Facesoffungi number: FoF 15008

Etymology – ***rufosquamosus***, refers to the red squamules on the surface of pileus.

Typification – China, Shanxi Province, Changzhi City, Qinyuan County, Lingkongshan Mountains, on the ground in broadleaf forest dominated by *Quercus* sp., 1510 m elev, 15 August 2022, N. Mao, MNM714 (holotype BJTC FM2687). GenBank: ITS = OR655155; nrLSU = OR655191; *tef1* = OR659992; *rpb2* = OR659943.

Basidiomata small to medium-sized. Pileus 15–58 mm diam; hemispherical to convex at a young age, then broadly convex to applanate, sometimes slightly depressed in the center; surface dry, distinctly cracked at maturity, densely covered with red (#e29280), dark red (#d6855f) to reddish brown (#b9854b) squamules; context up to 7 mm thick, solid, pale yellow (#e0da5f), turning blue (#63a9b4) when exposed. Hymenophore tubulose, adnate to sinuate, sometimes depressed around the stipe; surface bright yellow (#fbf966) at a young age, then yellowish brown (#e6c801) with age, turning blue (#63a9b4) when exposed; tubes concolorous with hymenophore surface, 3–10 mm long; pores angular or subround, 1–2 mm diam. Stipe 20–77 × 4–18 mm, central, cylindrical to subcylindrical, solid, equal or slightly enlarged downward; apical part yellow (#feff6e0), middle part yellowish-brown (#d1a11b) at a young age, then red (#d3a44e) to dark red (#a47c59) with age, basal part white (#dfebec) to cream white (#cee5e4), longitudinally fibrillose; context pale yellow (#faf992), unchanging in color when exposed. Basal mycelium whitish. Odor and taste are not recorded.

Basidiospores [120/2/6] (10–)11–14.5(–17) × 5–6.5(–7) μm, Q = (1.83–)2–2.4(–2.64), Q_{av} = 2.16 (± 0.18), subfusiform to fusiform in side view with slight suprahilar depression, subfusoid in face view, pale yellow to yellowish brown in water or 5% KOH, smooth. Basidia 30–50 ×12–16 μm, clavate, 4-spored, occasionally 2-spored. Hymenophoral trama boletoid-type, that is divergent,

with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 5–8 μm wide. Cheilocystidia 45–68 × 8–13 μm, narrowly subfusiform to fusoid-ventricose, pale yellow in water or 5% KOH, thin-walled, smooth, without encrustation. Pleurocystidia 50–90 × 7–17 μm, narrowly subfusiform, hyaline or pale yellow in water or 5% KOH, thin-walled, smooth, without encrustation. Pileipellis a palisadoderm consisting of vertically arranged, yellowish brown, more or less broadened and often incrusted hyphal elements; terminal cells 20–50(–62.5) × 6.5–15(–18) μm, which are subcylindrical to clavate, with obtuse apex cylindrical. Stipitipellis hymeniform, with caulocystidia 31–73 × 8–13 μm, subfusiform to fusoid, covered with pale yellow to pale brown extracellular pigments in water or 5% KOH. Clamp connections are absent.

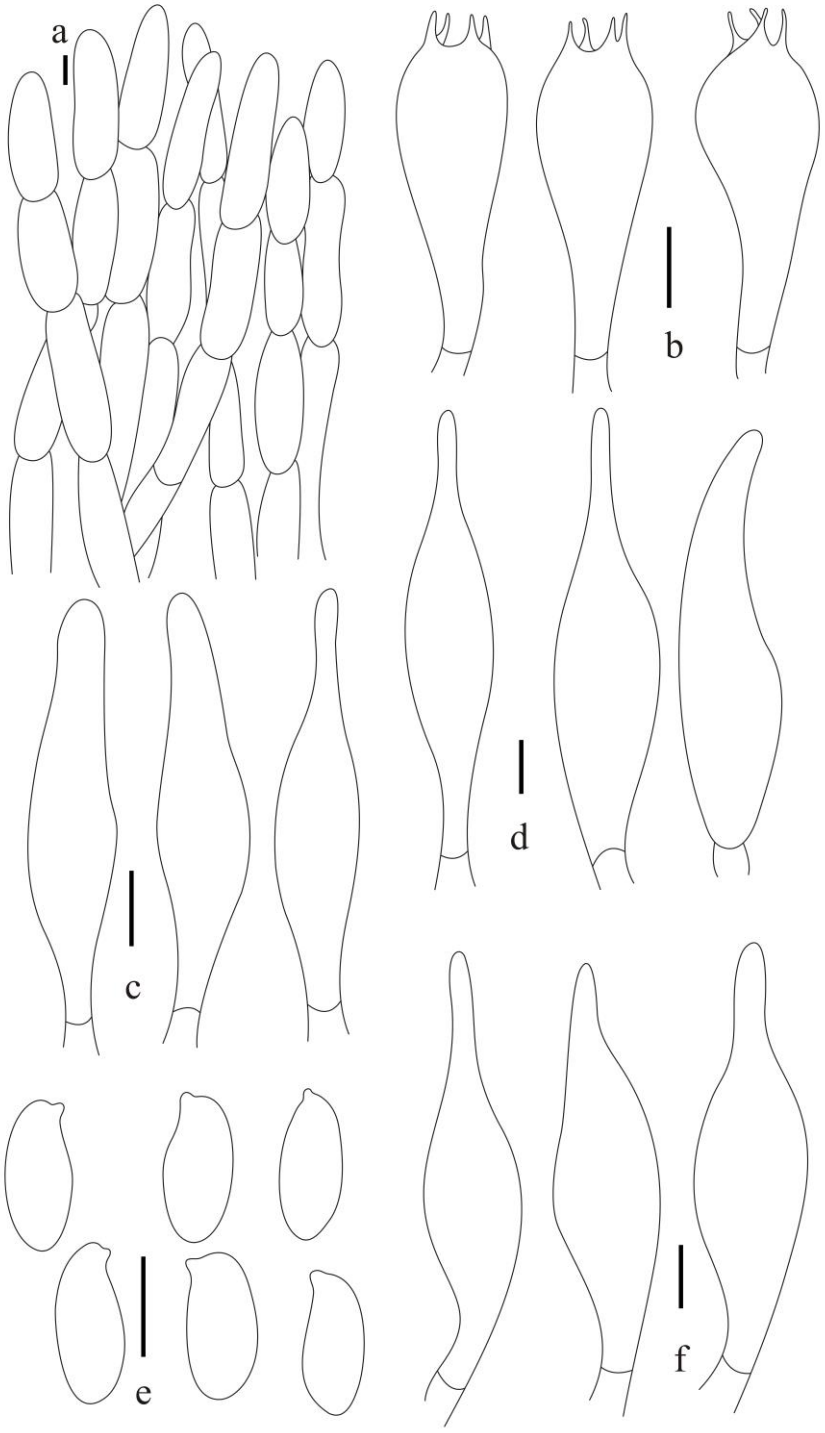

Figure 12 – *Hortiboletus rufosquamosus.* a Pileipellis. b Basidia. c Caulocystidia. d Pleurocystidia. e Basidiospores. f Cheilocystidia. Scale bars: a–f = 10 μm.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest dominated by *Quercus* spp., currently only known from Shanxi Province, northern China.

Other specimens examined – China, Shanxi Province, Changzhi City, Qinyuan County, Lingkongshan Mountains, on the ground in broadleaf forest dominated by *Quercus* sp., 1540 m elev, 15 August 2022, J.C. LV, LJC300 (BJTC FM2649); *ibid*, 1510 m elev, 15 August 2022, J.C. LV, LJC303 (BJTC FM2652); *ibid*,, 1450 m elev, 15 August 2022, J.C. LV, LJC311 (BJTC FM2660); *ibid*,, 1510 m elev, 15 August 2022, N. Mao, MNM707 (BJTC FM2680); Jinzhong City, Heshun County, on the ground in broadleaf forest dominated by *Quercus* sp., H. Liu, LH1615 (BJTC FM2692). Jincheng City, Qinshui County, on the ground in mixed forest, 1770.3 m elev, 11 August 2022, N. Mao, MNM602 (BJTC FM2290).

Note – *Hortiboletus rufosquamosus* is characterized by its distinctly cracked pileus densely covered with red, dark red to reddish brown squamules, multi-colored stipe with longitudinally fibrillose, and relatively larger basidia. *Hortiboletus kohistanensis* A. Naseer, S. Sarwar & A.N. Khalid is phylogenetically closely related to the new species. Their stipe is all covered with longitudinally fibrillose and both are all distributed in Asia. However, *Ho. kohistanensis* is distinguished from the new species by its pileal context and hymenium turning brown when exposed, and relatively smaller basidiospores (9–11 × 4–5.3 μm) (Naseer et al. 2019). The North American *Ho. rubellus* is morphologically similar to the new species. Both of them are actually difficult to separate from each other by morphology alone (Watling 1970, Bessette et al. 2017). The potential diagnostic feature might be the basidiospore shape that is ellipsoid in *Ho. rubellus* but subfusiform to fusiform in the new species. Moreover, *Ho. rubellus* often appears in city gardens and disturbed environments, but the new species grows only in natural forest associated with oaks according to current data. *Hortiboletus napaeus*, recently described from Hainan Province, southern China, is somewhat similar to *Ho. rufosquamosus* in stipe covered with longitudinally fibrillose and stipe context unchanging in color when exposed. However, *Ho. napaeus* is different in pale brown to brown stipe, smaller basidiospores (9–11 × 4–5) μm, and smaller basidia (20–35 × 9–14 μm) (Xie et al. 2020).

Hortiboletus tomentosus L. Fan, N. Mao & T.Y. Zhao, sp. nov. Figs 9c, 13

MycoBank number: MB 850263; Facesoffungi number: FoF 15009

Etymology –***tomentosus***, refers to the fine hairs on the surface of pileus.

Typification – China, Shanxi Province, Jincheng City, Qinshui County, Shangchuan Village, on the ground in broadleaf forest dominated by *Quercus* sp., 1770 m elev, 11 August 2022, N. Mao, MNM601-A (holotype BJTC FM2289-A). GenBank: nrLSU = OR655193; *tef1* = OR659994; *rpb2* = OR659945.

Basidiomata small to medium-sized. Pileus 15–58 mm diam; broadly convex at a young age, then gradually applanate with margin turning upwards with age; surface dry, finely tomentose, liver brown (#905021) to dark red-brown (#6c442b); context up to 9 mm thick, solid, pale yellow (#f6f493), unchanging in color when exposed. Hymenophore tubulose, adnate to decurrent; surface bright yellow (#f6f493) to yellow (#eae069), unchanging in color when exposed; tubes concolorous with hymenophore surface, up to 8 mm long; pores angular or subround, 1–2 mm diam. Stipe 35–58 × 6–10 mm, central, cylindrical to subcylindrical, solid, equal; yellow (#fdf4be) to yellowish brown (#cbae80), longitudinally fibrillose; context pale yellow (#fdf8c8), unchanging in color when exposed. Basal mycelium whitish. Odor and taste are not recorded.

Basidiospores [120/2/6] (10.5–)11–13 × 4.5–5(–5.5) μm, Q = 2.3–2.78, Q_{av} = 2.45 (± 0.15), subfusiform to fusiform in side view with slight suprahilar depression, subfusoid in face view, pale yellow to yellowish brown in water or 5% KOH, smooth. Basidia 28–43 × 11–13(–14) μm, clavate, 4-spored, occasionally 2-spored, sterigmata 5–6 μm long. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 5–9 μm wide. Cheilocystidia 55–85 × 9–13 μm, narrowly subfusiform to fusoid-ventricose, pale yellow or pale brown in water or 5% KOH, thin-walled, smooth, without encrustation. Pleurocystidia similar to cheilocystidia in shape and size. Pileipellis a palisadoderm consisting of vertically

arranged, yellowish brown, more or less broadened and often incrusted hyphal elements; terminal cells 13–40 × 11–14(–21.5) µm, subcylindrical to clavate, with obtuse apex cylindrical. Stipitipellis hymeniform, with caulocystidia 30–55 × 6–15 µm, subfusiform to fusoid, covered with pale yellow to pale brown extracellular pigments in water or 5% KOH. Clamp connections are absent.

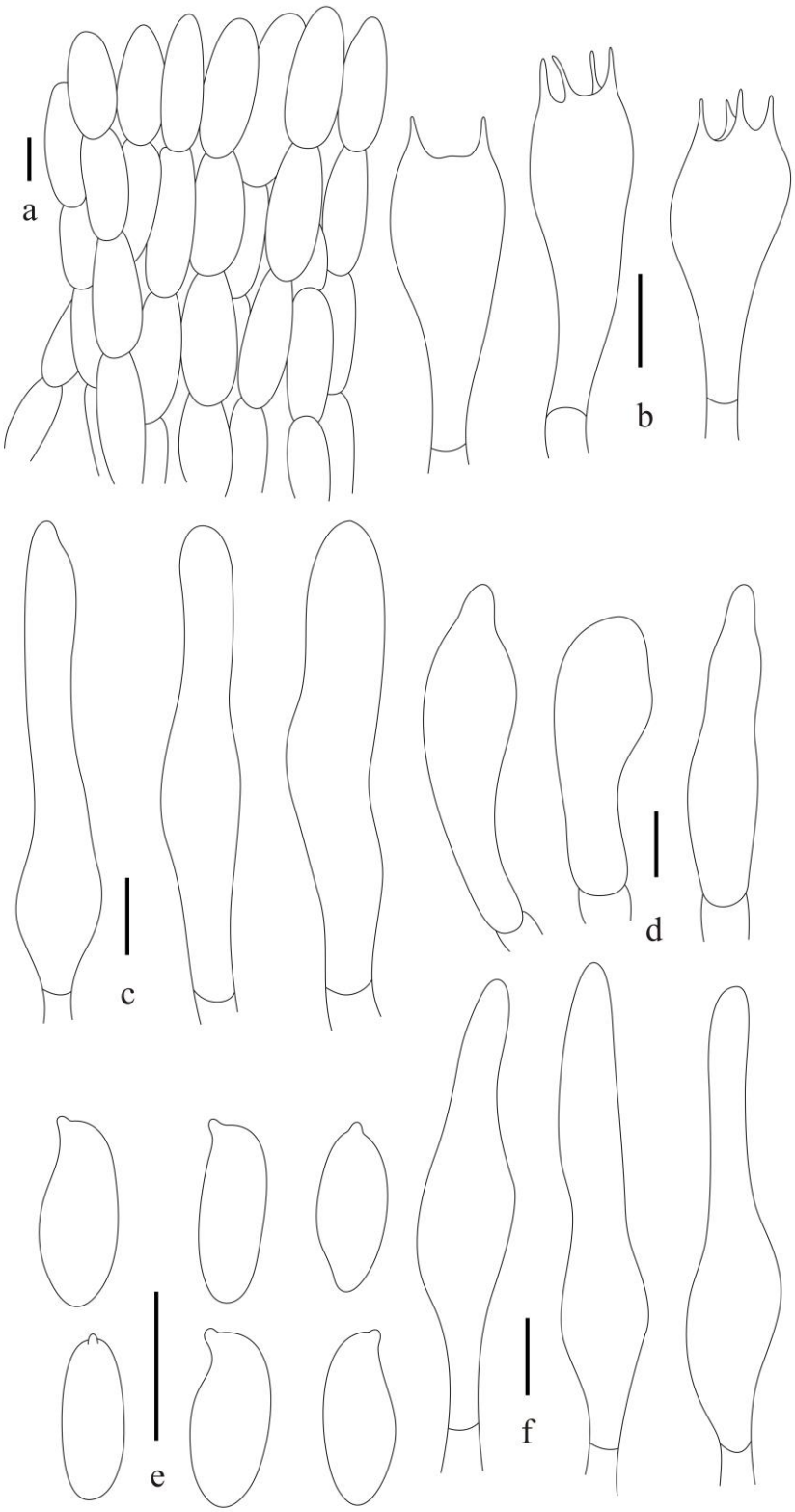

Figure 13 – *Hortiboletus tomentosus.* a Pileipellis. b Basidia. c Cheilocystidia. d Caulocystidia. e Basidiospores. f Pleurocystidia. Scale bars: a–e = 10 µm.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest dominated by *Quercus* spp., currently only known from Shanxi Province, northern China.

Other specimens examined – China, Shanxi Province, Jincheng City, Qinshui County, Shangchuan Village, on the ground in broadleaf forest dominated by *Quercus* sp., 1770 m elev, 11 August 2022, N. Mao, MNM601-B (BJTC FM2289-B).

Note – *Hortiboletus tomentosus* is characterized by its basidiomata unchanging in color when exposed, liver brown and tomentose pileus. *Hortiboletus tomentosus* was phylogenetically sister to *Ho*. *amygdalinus*, a new species found in Yunnan Province, southwestern China. However, *Ho*. *amygdalinus* differs from *Ho*. *tomentosus* by its hymenophore turning blue quickly when exposed and smaller pores (0.5–1 mm diam) (Wu et al. 2016a). Another new species *Ho*. *rufosquamosus* in this study, which was also collected in Shanxi Province, is similar to *Ho*. *tomentosus* in morphology, but it is distinguished by its basidiomata turning blue when bruised.

Leccinum Gray, Nat. Arr. Brit. Pl. (London) 1: 646 (1821)

MycoBank number: MB 17918; Facesoffungi number: FoF 14991

Notes – *Leccinum* was established to accommodate *Boletus aurantiacus* Bull. and its allies, which have whitish hymenophore turning brownish to blackish when exposed, brown to blackish squamules or dots and longitudinal ridges on the surface of the stipe, and comparatively longer smooth basidiospores (Wu et al. 2016a, Meng et al. 2021, Wang et al. 2023). A total of 11 species of *Leccinum* are currently recorded in China, i.e. *L. album* X. Meng, Yan C. Li & Zhu L. Yang, *L. aurantiacum* (Bull.) Gray, *L. melaneum* (Smotl.) Pilát & Dermek, *L. pallidocastaneum* P.M. Wang, X. Meng, Zhu L. Yang & Yan C. Li, *L. parascabrum* X. Meng, Yan C. Li & Zhu L. Yang, *L. phaeocarpum* P.M. Wang, X. Meng, Zhu L. Yang & Yan C. Li, *L. pseudoborneense* X. Meng, Yan C. Li & Zhu L. Yang, *L. scabrum* (Bull.) Gray, *L. schistophilum* Bon, *L. subleucophaeum* var. *minimum* Z.S. Bi and *L. versipelle* (Fr.) Snell. In this paper, two known species discovered from Shanxi Province of northern China are documented as follows.

Leccinum* cf. *aurantiacum (Bull.) Gray, Nat. Arr. Brit. Pl. (London) 1: 646 (1821)

Figs 9f–h, 14

MycoBank number: MB 101071; Facesoffungi number: FoF 15010

Basidiomata small to medium-sized. Pileus 24–98 mm diam, convex at a young age, then broadly convex, deflexed margin extending over tubes with irregularly shaped flaps; surface yellowish brown (#dabca0), orange-red (#e1b297) to reddish-brown (#fd825f); context up to 16 mm thick, solid, white (#d4dddc), unchanging in color when exposed. Hymenophore tubulose, adnate, surface greyish white (#d7eef0), turning brownish grey (#e3dfca) when exposed; tubes concolorous with hymenophore surface, up to 16 mm long. Stipe 70–130 × 11–19 mm, central, cylindrical, solid, equal or slightly enlarged downwards, white (#fcfcfa) at first, then turning yellowish brown (#c8c1ae) with age; surface covered with yellowish brown (#b0978e), orange-brown (#8b7053) to black (#2c160d) squamules over the stipe, sometimes reticulate; context white (#d9effc), sometimes turning blue (#afdff3) when exposed. Basal mycelium white (#ffffff). Odor and taste are not recorded.

Basidiospores [120/2/3] (11)12–16 × 4–5 μm, Q = (2.4–)2.6–3.2(–3.56), Q_{av} = 2.88 (± 0.25), subfusiform to fusiform with slight suprahilar depression, yellowish in water or 5% KOH, smooth. Basidia 23–33(–35) × 9–12(–13) μm, clavate, hyaline to yellowish in water or 5% KOH, 4-spored, occasionally 2- or 3-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 5–10 μm wide. Cheilocystidia 41–56 × 9–14(–17) μm, subfusiform, fusiform to lageniform, hyaline, thin-walled, smooth. Pleurocystidia 38–58 × 9–13, similar to cheilocystidia in shape. Pileipellis a trichoderm, composed of cylindrical hyphae, terminal elements 38–48 × 8–11 μm, thin-walled, always with pale brown to pale yellow extracellular pigments. Caulocystidia 30–60×12–24 μm, lageniform to clavate, hyaline. Clamp connections are absent.

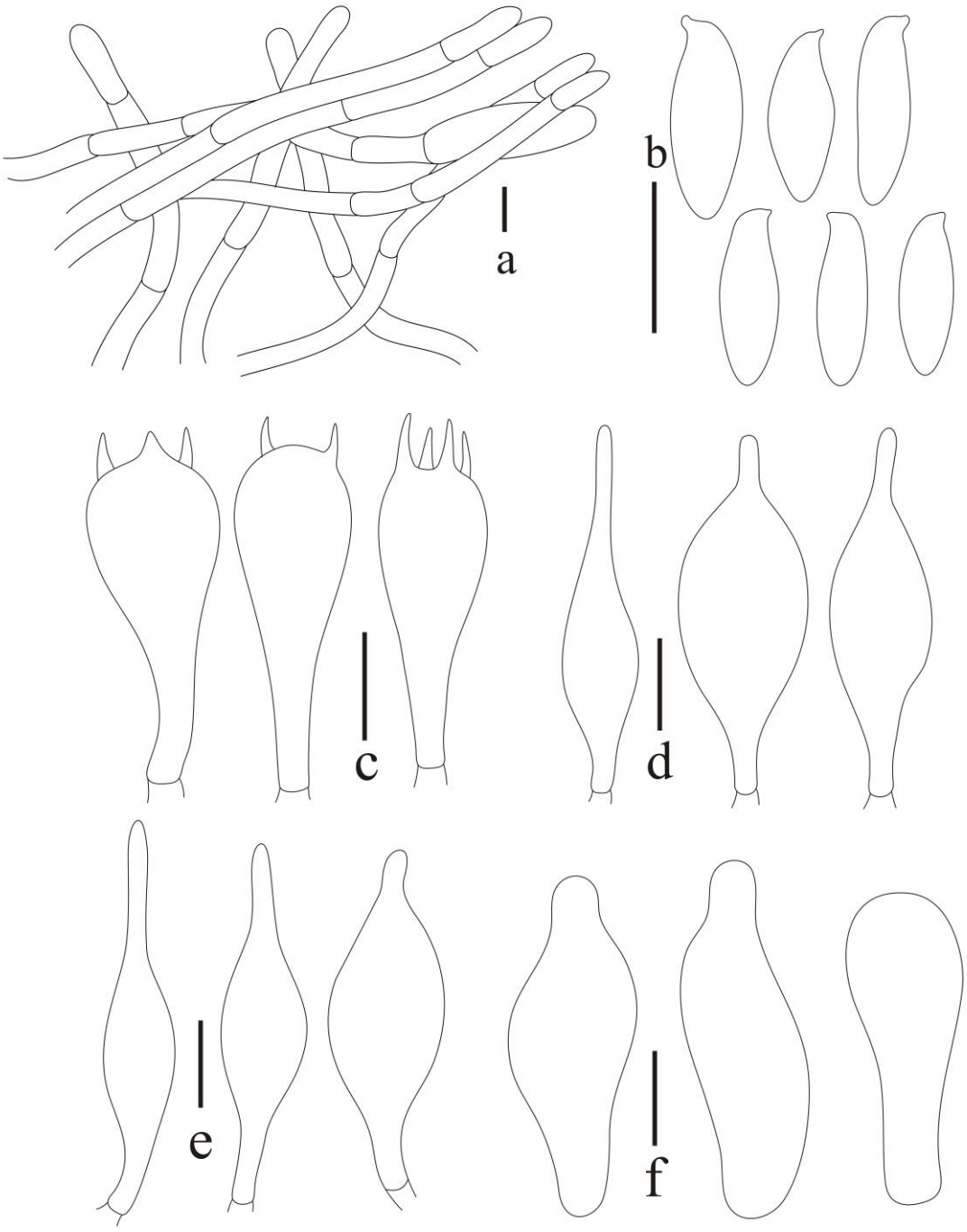

Figure 14 – *Leccinum* cf. *aurantiacum*. a Pileipellis. b Basidiospores. c Basidia. d Cheilocystidia. e Pleurocystidia. f Caulocystidia. Scale bars: a–d = 10 μm.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest or coniferous and broadleaf mixed forest, currently known in China, Europe and North America.

Specimens examined – China, Shanxi Province, Huozhou City, Qiliyu Village, on the ground in mixed forest, 1810 m elev, 29 July 2021, N. Mao, CF1211 (BJTC FM1927); Linfen City, Pu Village, Wulu Mountains, on the ground in broadleaf forest dominated by *Quercus* sp., 1510 m elev, 9 August 2022, J.C. Lv, LJC163 (BJTC FM2191); *ibid.*, 1512.7 m elev, N. Mao, MNM660 (BJTC FM2419); Lvliang City, Fenyang County, on the ground in broadleaf forest dominated by *Quercus* sp., 1400 m elev, 1 September 2022, J.Z. Cao, CF1146 (BJTC FM2742).

Note – *Leccinum* cf. *aurantiacum* designated here for these Shanxi samplings is mainly based on their similarity to *L. aurantiacum* in morphology, i.e. typically reddish cap and distinct scabers

on the stem surface. It is notable that the discoloration of the context has not been observed from these specimens, and all the samples grow exclusively in the oaks (*Quercus* spp.), therefore, it is different from the current concept of *L. aurantiacum* (Das & Chakraborty 2014). However, our present phylogenetic analysis cannot separate these Shanxi samples from *L. aurantiacum* and its allies (Fig. 1). Considering the fact that the authentic DNA data including LSU, *tef1*, and *rpb2* from *L. aurantiacum* is still in question, we designate these Shanxi specimens as *Leccinum* cf. *aurantiacum* for the time being. This species is frequently encountered under oaks from Summer to early Autumn in Shanxi Province, and its distribution almost completely overlapped with *Villoboletus persicinus* L. Fan & N. Mao, a species probably native to Shanxi Province, in central region.

Leccinum* cf. *scabrum (Bull.) Gray, Nat. Arr. Brit. Pl. (London) 1: 647 (1821)

Figs 9i–l, 15

MycoBank number: MB 100712; Facesoffungi number: FoF 15011

Basidiomata small to medium-sized. Pileus 35–105 mm diam, convex to broadly convex at a young age, then gradually applanate; surface dry, pale brown (#fff5d6), yellowish brown (#f1c49d), brown (#a47163) to dark brown (#674d4e); context up to 16 mm thick, solid, white (#ffffff), unchanging in color when exposed. Hymenophore tubulose, adnate, surface white greyish white (#e1dbda) at first, then turning brownish grey (#f1c49d) with age; tubes concolorous with hymenophore surface, up to 18 mm long; pores angular or subround. Stipe 57–13.5 × 8–35 mm, central, cylindrical, solid, equal or slightly enlarged downwards, white to brown (#acab88); surface covered with blackish (#6b5439) to brownish (#77653e) squamules over the stipe; context white yellow (#d4d3b1), unchanging in color when exposed. Basal mycelium white. Odor and taste are not recorded.

Basidiospores [120/2/3] 15–20 × 4–6.5 μm, Q = 2.9–3.75, Q_{av} = 3.2 (± 0.27), subfusiform to fusiform with slight suprahilar depression, yellowish in water or 5% KOH, smooth. Basidia 22–41 × 9–15 μm, clavate, hyaline to yellowish in water or 5% KOH, 4-spored, occasionally 2- or 3-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 4–11 μm wide. Cheilocystidia 34–62 × 9–13 μm, subfusiform, fusiform to lageniform, hyaline, thin-walled, smooth. Pleurocystidia similar to cheilocystidia in shape and size. Pileipellis a trichoderm, composed of interwoven hyphae 3–8 μm wide, smooth, thin-walled, always with pale brown to pale yellow extracellular pigments, terminal cells 25–50×9–12 μm, thin-walled, always with pale brown to pale yellow extracellular pigments. Caulocystidia 33–78×12–19 μm, lageniform to clavate, hyaline. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in coniferous forest or coniferous and broad-leaved mixed forest, currently known in China, Europe and North America.

Specimens examined – China, Shanxi Province, Xinzhou City, Wutai County, Wutai Mountains, on the ground in broadleaf forest dominated by *Betula* sp., 2000 m elev, 26 August 2019, Y. Shen, SYM039 (BJTC FM817); Taiyuan City, Loufan County, on the ground in broadleaf forest dominated by *Populus* sp., 10 September 2020, H. Liu, LH1296 (BJTC FM1462); Huozhou City, Qiliyu Village, on the ground in mixed forest, 1850 m elev, 29 July 2021, N. Mao, CF1206 (BJTC FM1923); *ibid.*, on the ground in broadleaf forest dominated by *Quercus* sp., 1870 m elev, 7 August 2022, N. Mao, MNM513 (BJTC FM2119); Linfen City, Pu County, Wulu Mountains, on the ground in broadleaf forest dominated by *Quercus* sp., 1760 m elev, 13 August 2022, J.C. Lv, LJC247 (BJTC FM2336); *ibid.*, 1508.1 m elev, 26 August 2022, N. Mao, MNM787 (BJTC FM2601); Changzhi City, Qinyuan County, Lingkong Mountains, on the ground in broadleaf forest dominated by *Quercus* sp., 2091.5 m elev, 15 August 2022, N. Mao, MNM694 (BJTC FM2667); Linfen City, Pu County, Wulu Mountains, on the ground in broadleaf forest dominated by *Quercus* sp., 7 September 2022, J.Z. Cao, LH1680 (BJTC FM2721); Lvliang City, Jiaocheng County, Pangquangou, Guandi Mountains, on the ground in broad leaved forest, 7 September 2017, J.Z. Cao, CAO170845 (BJTC FANM253).

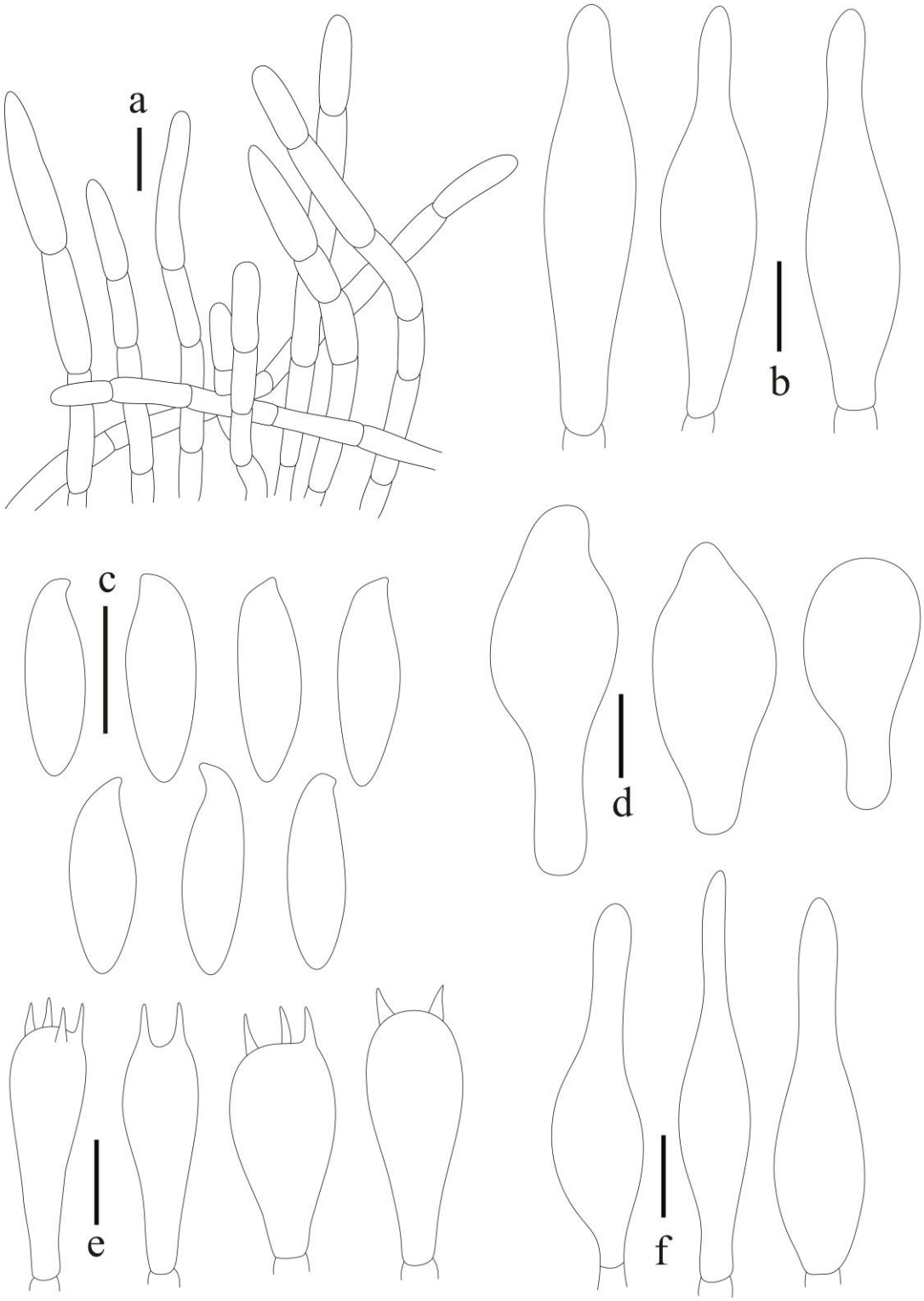

Figure 15 – *Leccinum* cf. *scabrum*. a Pileipellis. b Cheilocystidia. c Basidiospores. d Caulocystidia. e Basidia. f Pleurocystidia. Scale bars: a–d = 10 μm.

Note – *Leccinum* cf. *scabrum* designated here may represent a species complex by Shanxi samples. These specimens under this name are collected from different forest types, respectively dominant with birch (*Betula* spp.), aspen (*Populus* spp.) and oak (*Quercus* spp.), which is clearly different from one of the key identification features of *L. scabrum*, i.e. an association with birth (Bessette et al. 2017). Our molecular phylogenetic analysis did not resolve Shanxi samples into different species based on different host, and they also cannot be separated well from *L. scabrum*

and its allies (Fig. 1). Considering the fact that the authentic DNA data including LSU, *tef1*, and *rpb2* from *L. scabrum* is still in question, we designate our specimens as *Leccinum* cf. *scabrum* for the time being.

Neoboletus Gelardi, Simonini & Vizzini, Index Fungorum 192: 1 (2014)

MycoBank number: MB 550769; Facesoffungi number: FoF 14992

Notes – *Neoboletus* was established to accommodate *Boletus luridiformis* Rostk. and its allies. Morphologically, this genus is characterized by stipitate-pileate or sequestrate basidiomata; and when basidiomata are stipitate-pileate, which is diagnosed by yellow-olive tubes, stipe surface usually covered with punctuations, turning blue quickly when exposed, ellipsoid-fusiform basidiospores, and trichodermal pileipellis (Vizzini 2014c, Urban & Klofac 2015, Wu et al. 2016a, Chai et al. 2019, Gelardi et al. 2019, Jiang et al. 2021, Wu et al. 2023). There are about 23 names retained in Index Fungorum, sixteen of which are recorded in China, i.e. *N. brunneissimus* (W.F. Chiu) Gelardi, Simonini & Vizzini, *N. brunneorubrocarpus* G. Wu, Hai J. Li & Zhu L. Yang, *N. ferrugineus* (G. Wu, Fang Li & Zhu L. Yang) N.K. Zeng, H. Chai & Zhi Q. Liang, *N. flavidus* (G. Wu & Zhu L. Yang) N.K. Zeng, H. Chai & Zhi Q. Liang, *N. hainanensis* (T.H. Li & M. Zang) N.K. Zeng, H. Chai & Zhi Q. Liang, *N. infuscatus* N.K. Zeng, S. Jiang & Zhi Q. Liang, *N. magnificus* (W.F. Chiu) Gelardi, Simonini & Vizzini, *N. multipunctatus* N.K. Zeng, H. Chai & S. Jiang, *N. obscureumbrinus* (Hongo) N.K. Zeng, H. Chai & Zhi Q. Liang, *N. rubriporus* (G. Wu & Zhu L. Yang) N.K. Zeng, H. Chai & Zhi Q. Liang, *N. sanguineoides* (G. Wu & Zhu L. Yang) N.K. Zeng, H. Chai & Zhi Q. Liang, *N. sanguineu* (G. Wu & Zhu L. Yang) N.K. Zeng, H. Chai & Zhi Q. Liangs, *N. sinensis* (T.H. Li & M. Zang) Gelardi, Simonini & Vizzini, *N. thibetanus* (Shu R. Wang & Yu Li) Zhu L. Yang, B. Feng & G. Wu, *N. tomentulosus* (M. Zang, W.P. Liu & M.R. Hu) N.K. Zeng, H. Chai & Zhi Q. Liang, and *N. venenatus* G. Wu & Zhu L. Yang. The following new species is the seventeenth found in China.

Neoboletus cinnamomeus L. Fan, N. Mao & T.Y. Zhao, sp. nov. Figs 16a, 17

MycoBank number: MB 850264; Facesoffungi number: FoF 15012

Etymology – ***cinnamomeus***, refers to the overall cinnamon brown tone of basidiomata.

Typification – China, Shanxi Province, Jincheng City, Qinshui County, Tuwo Township, Shangwoquan Village, on the ground in broadleaf forest dominated by *Quercus* sp., 1168 m elev, 24 August 2020, H. Liu, LH1073 (holotype BJTC FM1055). GenBank: ITS = OR655157; nrLSU = OR655200; *rpb2* = OR659952.

Basidiomata small to medium-sized, overall, with a cinnamon brown tone. Pileus 35–45 mm diam.; hemispherical, convex to broadly convex; surface dry, finely tomentose, brown (#b47e52) to grey brown (#7a583f), dark brown (#af8266) at center, paler towards margin; context up to 6 mm thick, solid, pale yellow (#ebb626), turning blue (#007fb1) when exposed. Hymenophore tubulose, adnate; surface yellow (#ffd240) to yellow-brown (#93540c), turning blue (#3e82b9) when exposed; tubes yellow (#ffd240), up to 8 mm long; pores stuffed in early stages, then angular or subround, 0.5–1 mm diam. Stipe 50–80 × 8–12 mm, central, cylindrical to subcylindrical, solid, equal or slightly enlarged downward, usually flexuous, yellow (#ffd665) to yellowish brown (#9d7224); surface covered with fine yellowish brown (#9d7224) scales; context pale yellow (#fdea76), turning dark blue (#005889) when exposed. Basal mycelium brown. Odor and taste are not recorded.

Basidiospores [120/2/6] (10.5–)11–12.5(–13) × 5–6 μm, Q = (1.82–)2–2.4, Q_{av} = 2.18 (± 0.14), fusiform to ellipsoid in side view, sometimes with slight suprahilar depression, ellipsoid in face view, pale yellow to yellowish brown in water or 5% KOH, smooth. Basidia 36–50 × 9.5–12 μm, clavate, 4-spored, occasionally 2-spored. Hymenophoral trama boletoid type that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 5–8 μm wide. Cheilocystidia 35–46 × 8–10 μm, lageniform to fusoid-ventricose, hyaline or pale yellow in water or 5% KOH, thin-walled, smooth, without encrustation. Pleurocystidia 41.5–65 × 8.5–12.5 μm, similar to cheilocystidia in shape, hyaline or pale yellow in water or 5% KOH, thin-walled, smooth,

without encrustation. Pileipellis a trichoderm, composed of more or less vertically arranged, pale yellowish brown in KOH, thin-walled hyphae 3–5 µm diam, terminal cells 12–31 × 4–6 µm, subcylindrical to clavate. Stipitipellis a hymeniform, with caulocystidia 33–52 × 11–16 µm, fusoid, thin-walled. Clamp connections are absent.

Figure 16 – Fresh basidiomata of Boletaceae species. a *Neoboletus cinnamomeus* (BJTC FM1055). b-c *Retiboletus tingigriseus* (BJTC FM1736, BJTC FM2269). d–e *Rubroboletus reticulatus* (BJTC FM1784, BJTC FM1077). f *Strobilomyces strobilaceus* (BJTC FM1059). g–i *Suillellus olivaceus* (BJTC FM1874, BJTC FM2128, BJTC FM2285). j–l *Suillellus yunnanensis* (BJTC FM1814, BJTC FM2334, BJTC FM2337). Scale bars: a–l = 2 cm.

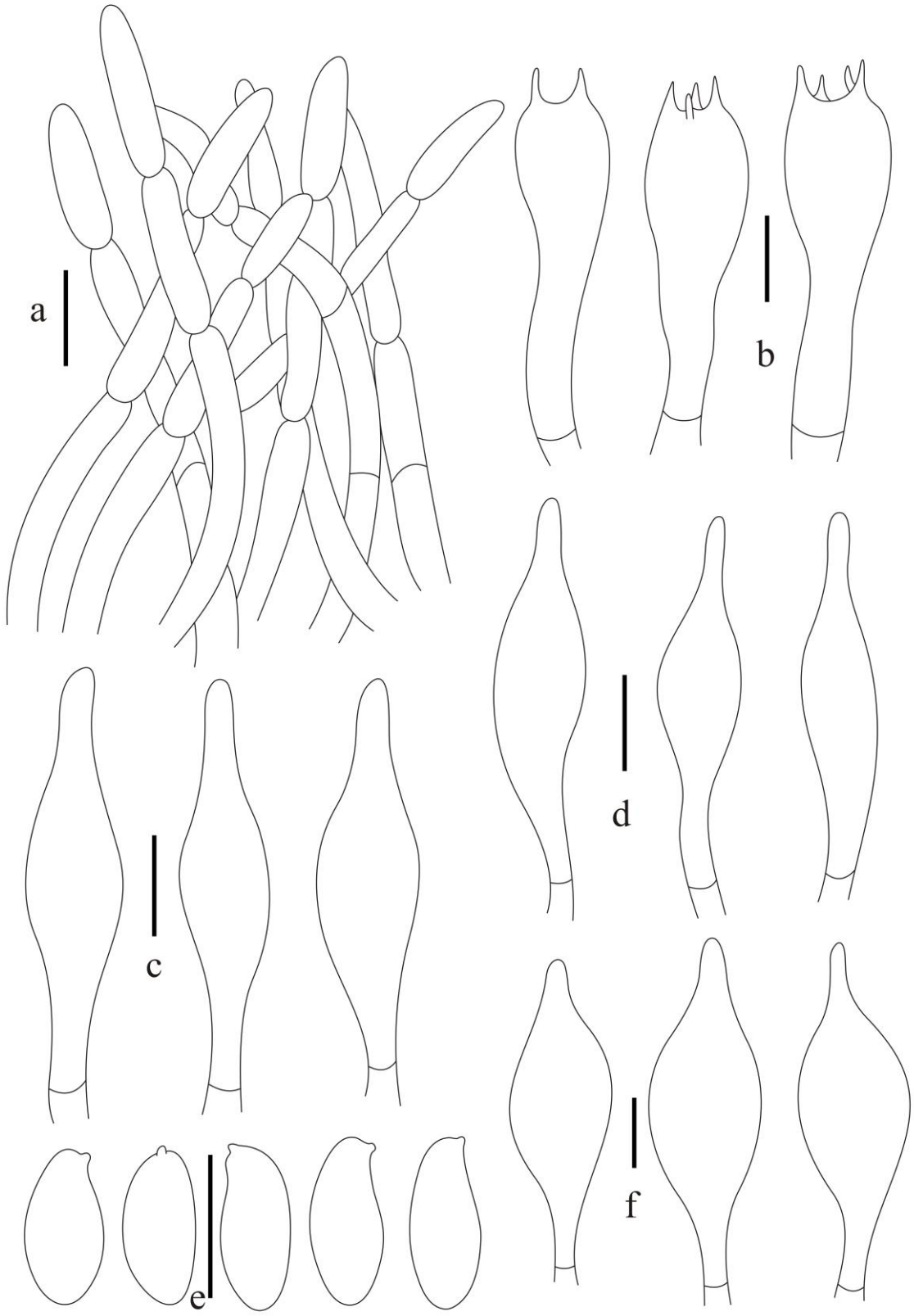

Figure 17 – *Neoboletus cinnamomeus.* a Pileipellis. b Basidia. c Pleurocystidia. d Cheilocystidia. e Basidiospores. f Caulocystidia. Scale bars: a–f = 10 μm.

Ecology and habitat – Solitary on the ground in broadleaf forest dominated by *Quercus* spp., currently only known from Shanxi Province, northern China.

Note – *Neoboletus cinnamomeus* is characterized by its brown pileus, yellow to yellow-brown hymenophore, stipe covered with fine yellowish-brown scales, turning dark blue when

exposed. *Neoboletus thibetanus* is phylogenetically closely related to the new species. But both species are easily distinguished by the color of pileus, which is light green-yellow, coral red to greyish yellow in *N. thibetanus*, but brown to dark brown in *N. cinnamomeus* (Wang et al. 2014). Morphologically, *N. multipunctatus*, known from tropical forests in Hainan Province of southern China (Chai et al. 2019), is similar to *N. cinnamomeus* as both of the two species have brown pileus and scales on stipe surface. However, *N. multipunctatus* has smaller basidiospores (8.5–11 × 4–5 μm) and a tropical habit, distinguishing it from *N. cinnamomeus*.

Retiboletus Manfr. Binder & Bresinsky, Feddes Repert. 113: 36 (2002).

MycoBank number: MB 28725; Facesoffungi number: FoF 14993

Notes – *Retiboletus* was established to accommodate *Boletus ornatipes* Peckand its allies. The genus is morphologically characterized by its black, dark grey, mustard yellow or olive-brown pileus, greyish or yellow hymenophore, unchanging in color when exposed, reticulate stipe, ellipsoid to subfusoid basidiospores (Binder & Bresinsky 2002, Wu et al. 2016a, Zeng et al. 2016, 2018, Badou et al. 2018, Liu et al. 2020, Li & Yang 2021, Li et al. 2022). There are about 17 species accepted in *Retiboletus* in Index Fungorum, seven of which are recorded in China, i.e. *R. ater* Yan C. Li & T. Bau, *R. brunneolus* Yan C. Li & Zhu L. Yang, *R. cyanescens* Yan C. Li & Zhu L. Yang, *R. fuscus* (Hongo) N.K. Zeng & Zhu L. Yang, *R. nigrogriseus* N.K. Zeng, S. Jiang & Zhi Q. Liang, *R. pseudogriseus* N.K. Zeng & Zhu L. Yang, and *R. zhangfeii* N.K. Zeng & Zhu L. Yang (Li & Yang 2021, Li et al. 2022). The following new species is the eighth found in China.

Retiboletus tingigriseus L. Fan, N. Mao & T.Y. Zhao, sp. nov. Figs 16b–c, 18

MycoBank number: MB 850265; Facesoffungi number: FoF 15013

Etymology – ***tingigriseus***, refers to the overall grey tone of basidiomata.

Typification – China, Shanxi Province, Jincheng City, Qinshui County, Shangchuan Village, on the ground in coniferous and broad-leaved mixed forest dominated by *Pinus* sp. and *Quercus* sp., 1760 m elev, 11 August 2022, J.C. Lv, LJC1073 (holotype BJTC FM2269). GenBank: nrLSU = OR655203; *tef1* = OR660002; *rpb2* = OR659955.

Basidiomata small to medium-sized Pileus 51–75 mm diam; broadly convex to applanate; surface dry, finely subtomentose, greyish brown (#cecac2) at first, then brown grey (#cbcac6) to dark grey (#67695d); context up to 11 mm thick, solid, white (#ffffff) to pale yellow (#e5efdf), unchanging in color when exposed. Hymenophore tubulose, adnate; surface creamy-white (#fffdd0) to pale yellow (#e3e7d2) at a young age, then brown (#c9a379) with age, unchanging in color when exposed; tubes concolorous with hymenophore surface, 4–9 mm long; pores angular to roundish, 1–2 mm wide. Stipe 61–100 × 9–16 mm, central, cylindrical to subcylindrical, solid, equal or slightly enlarged downward, greyish brown (#9f8a82) to brown (#a99b82); surface covered with distinct brown (#9e9087) to black brown reticulum (#6c5f5c), sometimes covered with brown (#63503b) granular squamules on the lower part; context white (#ffffff) to pale yellow (#fdfef0), unchanging in color when exposed. Basal mycelium white (#ffffff). Odor and taste are not recorded.

Basidiospores [60/2/2] 12–14 × 3.5–4.5 μm, Q = 3–3.5, Q_{av} = 3.23 (± 0.19), subfusiform to narrow fusiform in side view, sometimes with slight suprahilar depression, oblong to narrow ellipsoid in face view, pale yellow to yellowish brown in water or 5% KOH, smooth. Basidia 25–38 × 8–12 μm, clavate, 4-spored, occasionally 2-spored. Hymenophoral trama boletoid type that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 3–7 μm wide. Cheilocystidia 21–47 × 6–10 μm, subfusiform to fusoid-ventricose with a long pedicel, usually containing yellow to brownish yellow pigments, thin-walled. Pleurocystidia 44–67 × 9–14.5 μm, subfusiform to fusoid-ventricose, sometimes with a long pedicel, thin-walled. Pileipellis a trichoderm 100–160 μm thick, composed of brownish to yellowish-brown interwoven filamentous hyphae 5.5–10 μm in diam, terminal cells 12–42 × 5–10 μm, subcylindrical to clavate. Stipitipellis a hymeniform, with caulocystidia 27–60 × 8–14 μm, fusoid, thin-walled. Stipe trama composed of parallel hyphae 4–11 μm wide. Clamp connections are absent.

Ecology and habitat – Solitary on the ground in broadleaf forest dominated by *Quercus* spp., currently only known from Shanxi Province, northern China.

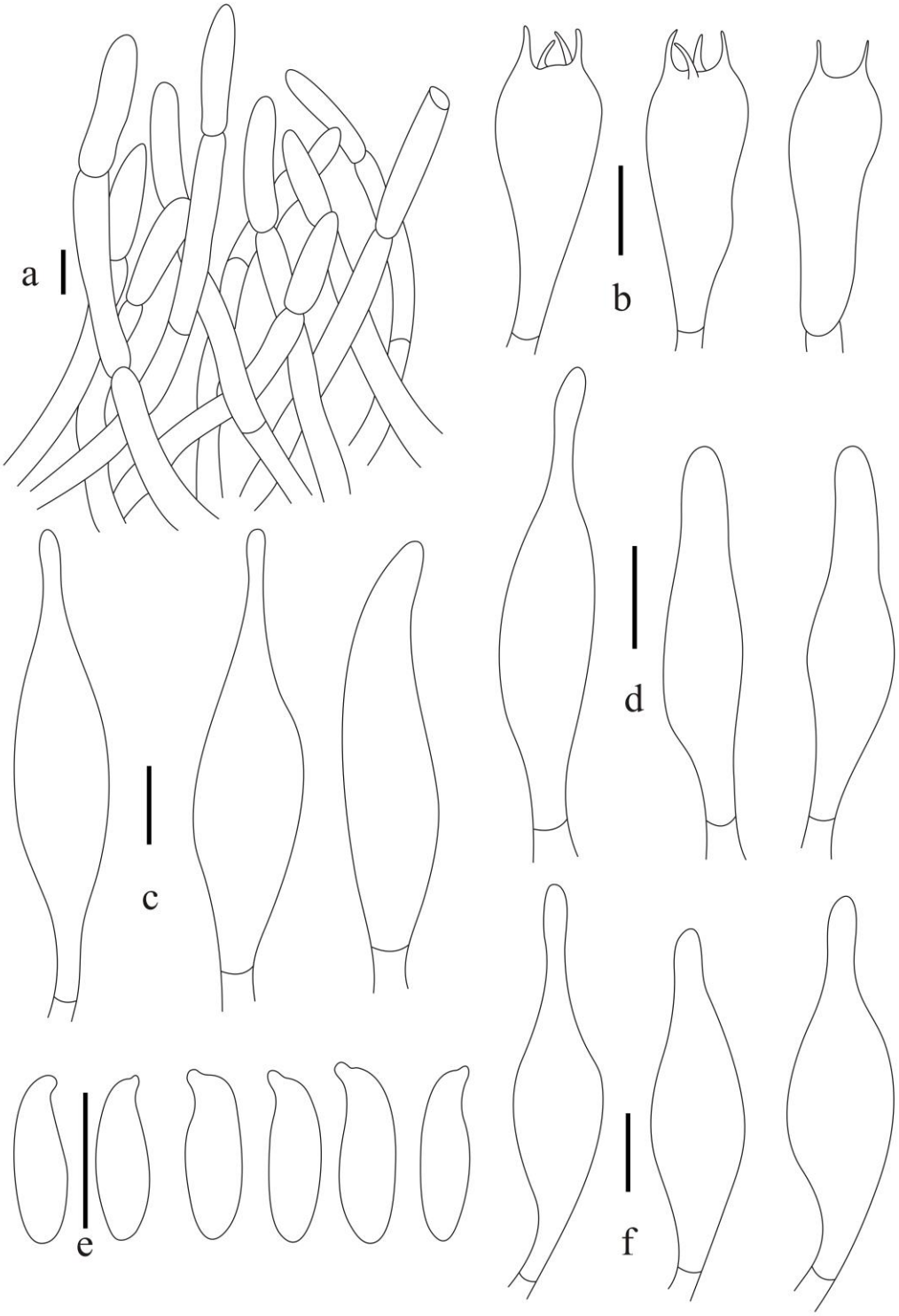

Figure 18 – *Retiboletus tingigriseus.* a Pileipellis. b Basidia. c Pleurocystidia. d Cheilocystidia. e Basidiospores. f Caulocystidia. Scale bars: a–f = 10 μm.

Other specimens examined – China, Shanxi Province, Jincheng City, Qinshui County, Shangchuan Village, on the ground in coniferous and broad-leaved mixed forest dominated by *Pinus* sp. and *Quercus* sp., 1760 m elev, 24 July 2021, N. Mao, MNM334 (BJTC FM1736); *ibid*, 24 July 2021, N. Mao MNM375 (BJTC FM1797).

Note – *Retiboletus tingigriseus* is characterized by its greyish brown to dark grey pileus, hymenophore with brown tones when mature, stipe covered with distinct brown to black brown reticulum, relatively narrow basidiospores. *Retiboletus tingigriseus* was phylogenetically closely related to both of *R. cyanescens* and *R. brunneolus*, two Chinese species described from Yunnan Province in southwestern China. And the three species all have grey-toned pileus. However, *R. cyanescens* is distinguished from the new species by its white hymenophore (without brown tones), stipes covered only with reticulations and without scales on the lower part, staining indistinct blue in the middle part, shorter and broader basidiospores (10–13 × 4–5 μm, Q_{av} = 2.6) (Li et al. 2022); *R. brunneolus* by its hymenophore dingy white to greyish white when mature, broader basidiospores (10–12.5 × 4.5–5 μm, Q_{av} = 2.21) (Li & Yang 2021).

Rubroboletus Kuan Zhao & Zhu L. Yang, Phytotaxa 188(2): 67 (2014)

MycoBank number: MB 809235; Facesoffungi number: FoF 14994

Notes – *Rubroboletus* (*Ru.*) was established to accommodate *Boletus sinicus* W.F. Chiuand its allies. The genus is morphologically characterized by its reddish pileus, orange-red to blood red hymenophore, stipe covered with reticula or spots, and an interwoven trichodermal pileipellis (Zhao et al. 2014b, Tibpromma et al. 2017, Zhao & Shao 2017). There are about 18 species retained in Index Fungorum, six of which are recorded in China, i.e. *Ru. esculentus* Kuan Zhao, H.M. Shao & Zhu L. Yang, *Ru. flammeus* N.K. Zeng, X. Zhang, W.Q. Qin, Z.Q. Liang& R. Tian, *Ru. flavus G.* Wu & Zhu L. Yang, *Ru. latisporus* Kuan Zhao & Zhu L. Yang, *Ru. serpentiformis* G. Wu, Hai J. Li & Zhu L. Yang, and *Ru. sinicus* (W.F. Chiu) Kuan Zhao & Zhu L. Yang (Zhao et al. 2014b, Zhao & Shao 2017, Wu et al. 2023). The following new species is the seventh found in China.

Rubroboletus reticulatus L. Fan, N. Mao & T.Y. Zhao, sp. nov. Figs 16d–e, 19

MycoBank number: MB 850266; Facesoffungi number: FoF 15014

Etymology – ***reticulatus***, refers to the reticulum on the upper part of stipe surface.

Typification – China, Shanxi Province, Jincheng City, Qinshui County, Tuwo Township, Shangwoquan Village, on the ground in broad leaved forest dominated by *Quercus* sp., 1090 m elev, 26 July 2021, N. Mao, MNM357 (holotype BJTC FM1784). GenBank: ITS = OR655160; nrLSU = OR655205; *tef1* = OR660004; *rpb2* = OR659957.

Basidiomata small to large-sized. Pileus 33–125 mm diam.; hemispherical to convex at a young age, then broadly convex to applanate with age; surface pale red (#ff7c8a), yellow red (#ff7c69) to scarlet red (#8a0918); context up to 15 mm, yellow (#ffffed), turning blue (#ade6f9) quickly when exposed. Hymenophore tubulose, adnate, sometimes depressed around apex of stipe when mature; surface red (#ee626d), orange-red (#f26e45) to orange (#e1604a), turning blue (#ade6f9) quickly when exposed; tubes concolorous with hymenophore surface, up to 7 mm long; pores roundish, 0.3–0.4 mm diam. Stipe 50–100 × 18–33 mm, central, cylindrical to subcylindrical, solid, often gradually enlarged or clavate towards the base, sometimes also obese, not rooting, orange-yellow (#e1bf80), orange-red (#e17d47) to red (#dc746e); surface covered with fine reticulum on the upper part; context yellow (#e4f6cd), turning blue (#659e80) quickly when exposed. Basal mycelium white. Odor and taste are not recorded.

Basidiospores [60/2/3] (10–)11–13(–13.5) × 4–5(–5.5) μm, Q = 2.2–2.78, Q_{av} = 2.47 (± 0.18), subfusiform to fusiform in side view, sometimes with slight suprahilar depression, fusiform in face view, pale yellow to yellowish brown in water or 5% KOH, smooth. Basidia 27–39 × (9–)10–12(–14) μm, clavate, 4-spored, occasionally 2-spored, sterigmata 4–5 μm long. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 3–9 μm wide. Cheilocystidia 27–40 × 6–8 μm, narrowly lageniform to lageniform, hyaline, thin-walled. Pleurocystidia 44–67 × 9–14.5 μm, similar to cheilocystidia in shape, thin-walled. Pileipellis an interwoven trichoderm, composed of more or less vertically arranged thin-walled, hyaline or pale brown filamentous hyphae 3–5 μm in diam., terminal cells

12–34 × 3–6 µm, subcylindrical to clavate. Stipitipellis a hymeniform, with caulocystidia 23–50 × 9–11 µm, fusoid, thin-walled. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest dominated by *Quercus* sp., currently only known from Shanxi province, northern China.

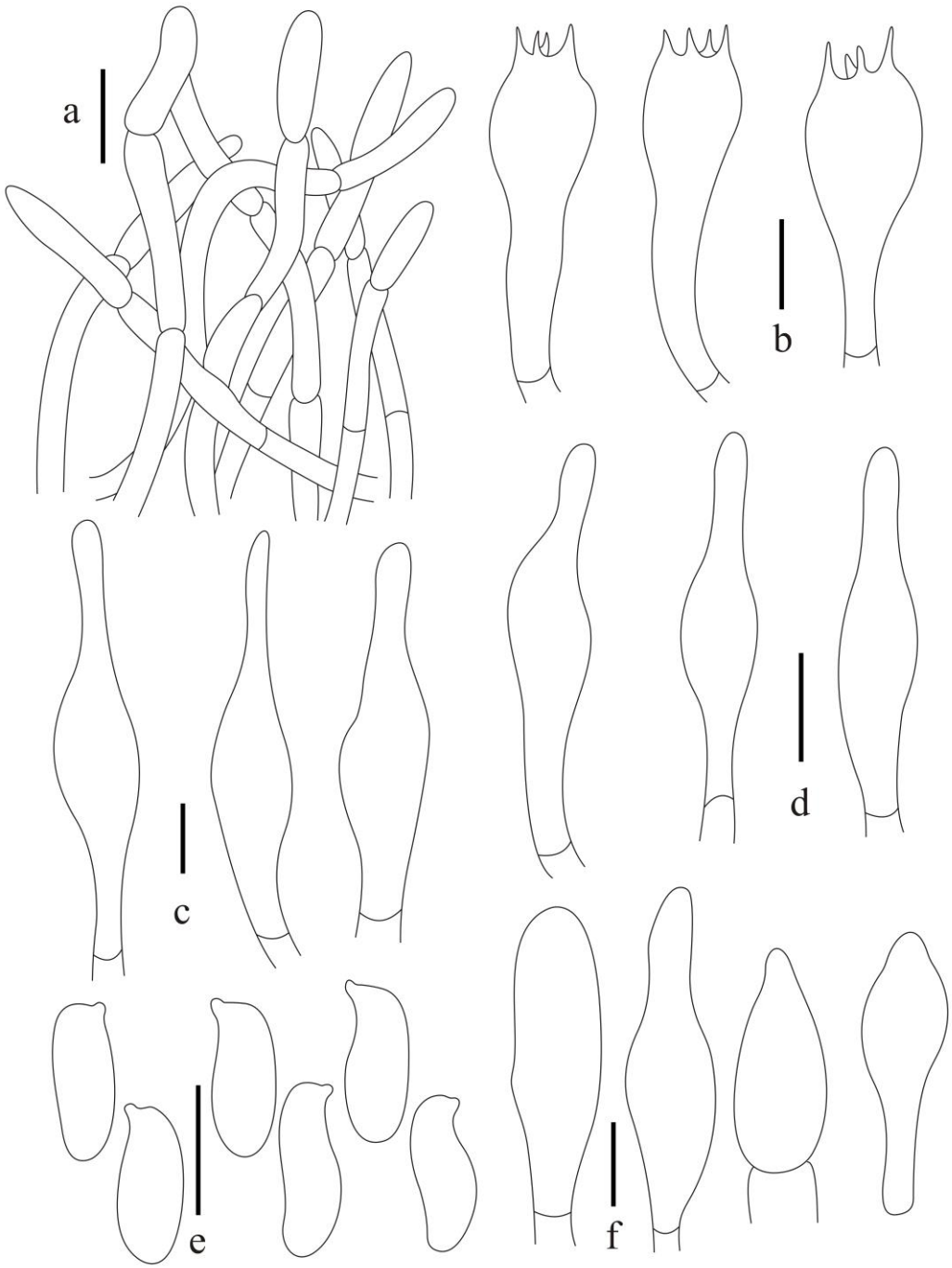

Figure 19 – *Rubroboletus reticulatus.* a Pileipellis. b Basidia. c Pleurocystidia. d Cheilocystidia. e Basidiospores. f Caulocystidia. Scale bars: a–f = 10 µm.

Other specimens examined – China, Shanxi Province, Jincheng City, Qinshui County, Tuwo Township, Shangwoquan Village, on the ground in broad leaved forest dominated by *Quercus* sp., 1170 m elev, 25 August 2020, J.C. Lv, LH1095 (BJTC FM1077); *ibid*, 1090 m elev, 25 July 2020, H. Liu, LJC042 (BJTC FM1812).

Note – *Rubroboletus reticulatus* is characterized by its red pileus, orange-yellow to orange-red stipe covered with fine reticulum on the upper part, and habitat associated with *Quercus*. Both of the European *Ru. dupainii* (Boud.) Kuan Zhao & Zhu L. Yang and the Chinese *Ru. latisporus* are highly similar and closely related to the new species in morphology and phylogeny. However, both of the two species can be separated from the new species by their slimy-viscid pileus when fresh and the stipe with punctate ornamentations rather than reticulate ones (Zhao et al. 2014b, Bessette et al. 2017), In addition microscopically, *Ru. dupainii* is distinguished from the new species by its inconspicuous hymenial cystidia; *Ru. latisporus* by its broader basidiospores (11–13 × 6–6.5 μm) (Zhao et al. 2014b).

Strobilomyces Berk., Hooker's J. Bot. Kew Gard. Misc. 3: 78 (1851)

MycoBank number: MB 18608; Facesoffungi number: FoF 14995

Notes – *Strobilomyces* was established to accommodate *Boletus strobilaceus* Scop. and its allies. The genus is morphologically characterized by its dark brown to blackish basidiomata, pileal surface covered with scales, and a distinct reddening or blackening discolouration when exposed (Singer 1986, Sato et al. 2011, Wu et al. 2016a, Han et al. 2020). A total of 26 species of *Strobilomyces* are currently recorded in southern China, i.e. *S. albidus* Li H. Han, J. Xu & Zhu L. Yang, *S. alpinus* M. Zang, Y. Xuan & K.K. Cheng, *S. anthracinus* Li H. Han, J. Xu & Zhu L. Yang, *S. atrosquamosus* J.Z. Ying & H.A. Wen, *S. brunneolepidotus* Har. Takah. & Taneyama, *S. calidus* Li H. Han, J. Xu & Zhu L. Yang, *S. cingulatus* Li H. Han & Zhu L. Yang, *S. densisquamosus* Li H. Han & Zhu L. Yang, *S. douformis* Li H. Han & Zhu L. Yang, *S. echinocephalus* Gelardi & Vizzini, *S. foveatus* Corner, *S. giganteus* M. Zang, *S. glabellus* J.Z. Ying, *S. glabriceps* W.F. Chiu, *S. latirimosus* J.Z. Ying, *S. microreticulatus* Li H. Han & Zhu L. Yang, *S. mirandus* Corner, *S. mollis* Corner, *S. montosus* Berk., *S. parvirimosus* J.Z. Ying, *S. pinophilus* Li H. Han & Zhu L. Yang, *S. pteroreticulosporus* Antonín & Vizzini, *S. seminudus* Hongo, *S. strobilaceus* (Scop.) Berk., *S. subnudus* J.Z. Ying, and *S. velutinus* J.Z. Ying. In this paper, a known species discovered from Shanxi Province of northern China is documented as follows.

Strobilomyces strobilaceus (Scop.) Berk., Hooker's J. Bot. Kew Gard. Misc. 3: 78 (1851)

Figs 16f, 20

MycoBank number: MB 238002; Facesoffungi number: FoF 10113

Basidiomata small-sized. Pileus 18–36 mm diam, convex to applanate; surface dry, dark brown (#69514d) to greyish black (#2a232a), covered with conical or compressed scales; context whitish (#d9d5d2) to grayish (#b7b3b2), turning dark red (#45322b) to blackish (#342c1f) when exposed. Hymenophore tubulose, adnate, surface white (#ffffff) to grey (#b5b1b0), turning dark red (#45322b) to blackish (#342c1f) when exposed; tubes concolourous with the surface of hymenophore; pores angular, 0.5–1 mm diam. Stipe 27–60 × 5–10 mm, central, cylindrical to subcylindrical, solid, equal, concolorous to the pileus; surface covered with elongate reticula; context whitish (#b4b2be) to grayish (#a2a0ab), turning dark red (#9c99ac) to blackish (#736f7e) when exposed. Basal mycelium white (#ffffff). Odor and taste are not recorded.

Basidiospores [60/2/2] 10–13 × 8—10 μm, Q = 1.1–1.53, Q_{av} = 1.26 (± 012), subglobose to broadly ellipsoid in side view, sometimes with slight suprahilar depression, subglobose in face view, reticulate. Basidia 32–46 × 14–17 μm, clavate, 4-spored, occasionally 2-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and densely arranged lateral strata, hyphae cylindrical, 3–10 μm wide. Cheilocystidia 45–66 × 12–18 μm, fusiform to broadly fusiform. Pleurocystidia 47–71 × 10–18.5 μm, similar to cheilocystidia in shape. Pileipellis an interwoven trichoderm, composed of more or less vertically arranged thin-walled, pale brown hyphae 4–13 μm in diam., terminal cells 13–53 × 5–13, clavate. Stipitipellis a trichodermium composed of brownish to yellowish brown interwoven septate hyphae 5–12 μm wide, terminal cells 26–72 × 5.5–11 μm, subcylindrical to clavate. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest or coniferous and broadleaf mixed forest, currently known from Europe, East Asia and North/Central America.

Specimens examined – China, Shanxi Province, Jincheng City, Qinshui County, Shangwoquan Village, on the ground in broadleaf forest dominated by *Quercus* sp., 1148 m elev, 21 August 2019, Y.Y. Xu, XYYM42 (BJTC FM687); *ibid.*, on the ground in broadleaf forest, 1168 m elev, 25 August 2020, H. Liu, LH1077 (BJTC FM1059).

Note – *Strobilomyces strobilaceus* is characterized by its basidiomata turning dark red to blackish when exposed, medium-sized reticulate basidiospores, and wider basidia (Berkeley 1851, Petersen et al. 2012, Han et al. 2020). Rare, only harvested from the southern region of Shanxi Province.

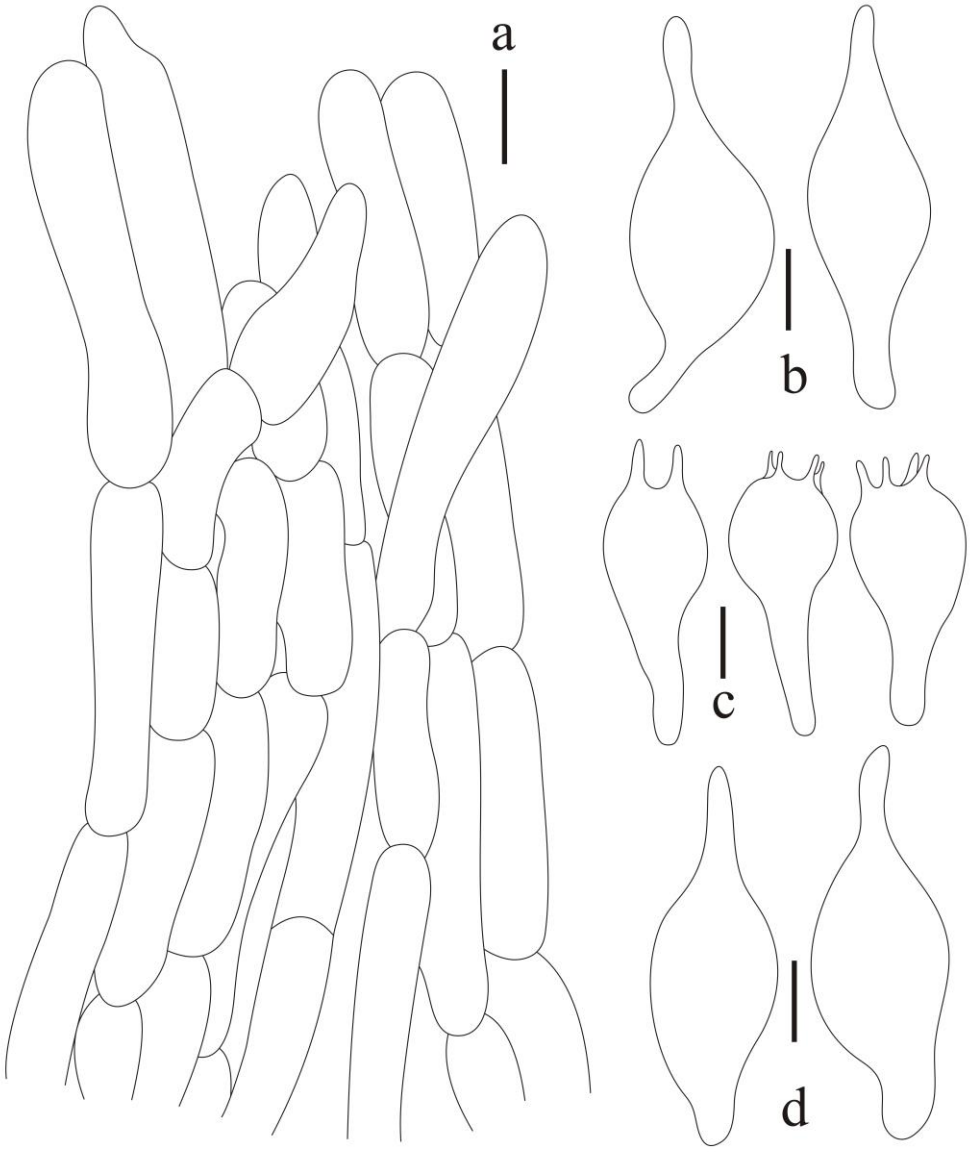

Figure 20 – *Strobilomyces strobilaceus*. a Pileipellis. b Cheilocystidia. c Basidia. d Pleurocystidia. Scale bars: a–c = 10 μm.

Suillellus Murrill, Mycologia 1: 16 (1909).

MycoBank number: MB 18620; Facesoffungi number: FoF 14996

Notes – *Suillellus* (*Su.*) was established to accommodate *Boletus luridus* Schaeff. and its allies. The genus is morphologically characterized by its yellowish brown to dark brown pileus,

turning blue when exposed, olive-yellow to yellowish brown hymenophore, stipes covered with yellow to brown reticula, and strongly amyloid hyphae at the stipe base (Vizzini et al. 2014, Wu et al. 2016a, Wang et al. 2022). There are about 21 species retained in Index Fungorum, eight of which are recorded in China, i.e. *Su. flaviporus* G. Wu, Hai J. Li & Zhu L. Yang, *Su. lacrymibasidiatus* Yang Wang, Bo Zhang & Yu Li, *Su. luridus* (Schaeff.) Murrill, *Su. pictiformis* Murrill, *Su. pinophilus* G. Wu, Hai J. Li & Zhu L. Yang, *Su. queletii* (Schulzer) Vizzini, Simonini & Gelardi, *Su. subamygdalinus* Kuan Zhao & Zhu L. Yang, and *Su. yunnanensis* G. Wu & Zhu L. Yang. In this paper, a new species and two known species discovered from Shanxi Province of northern China are documented as follows.

Figure 21 – Fresh basidiomata of Boletaceae species. a *Suillellus subamygdalinus* (BJTC FM2576). b *Tylopilus himalayanus* (BJTC FM2315). c *Villoboletus persicinus* (BJTC FM2439). d *Xerocomus ferrugineus* (BJTC FM2369). e–f *Xerocomus galbanus* (BJTC FM1790, BJTC FM1813). g–i *Xerocomus tenuistipitatus* (BJTC FM2267, BJTC FM2684). Scale bars: a–i = 2 cm.

Suillellus olivaceus L. Fan, N. Mao & T.Y. Zhao, sp. nov. Figs 16g–i, 22

MycoBank number: MB 850267; Facesoffungi number: FoF 15015

Etymology – ***olivaceus***, refers to the olive green color of pileus centre.

Typification – China, Shanxi Province, Jincheng City, Qinshui County, Lishan Mountains, on the ground in broad leaved forest dominated by *Quercus* sp., 1640 m elev, 25 July 2021, J.C. Lv, LJC015 (holotype BJTC FM1755). GenBank: ITS = OR655167; nrLSU = OR655212; *tef1* = OR660011; *rpb2* = OR659964.

Basidiomata small, medium to large-sized. Pileus 25–150 mm diam; hemispherical to convex at a young age, then broadly convex to applanate; surface dry, finely tomentose, color varing in a wide range, pale red (#e4876b), rust red (#c86158), rust reddish (#9e5749) with olive (#b69d61) center to whole olive green (#bd9959); context up to 20 mm thick, white (#ffffff), cream white (#f2f2ee) to pale yellow (#fafce3), turning blue (#b2e0fa) quickly when exposed. Hymenophore tubulose, adnate, sometimes depressed around apex of stipe; surface orange-yellow (#d48a32), orange-red (#883805) to scarlet red (#863415), turning dark blue (#383864) quickly when exposed; tubes bright yellow (#f5e195), 2–10 mm long; pores roundish, 0.3–0.7 mm diam. Stipe 55–170 × 10–25 mm, central, cylindrical to subcylindrical, solid, equal or slightly enlarge downwards, yellow (#ffe687) to orange-yellow (#cc9051) at upper part, orange-yellow (#cc9051) or purplish red (#d4a598) downwards; surface covered with longitudinal reticula all over the stipe; context pale yellow (#f2f6df), turning blue (#93b8ca) quickly when exposed. Basal mycelium white. Odor and taste are not recorded.

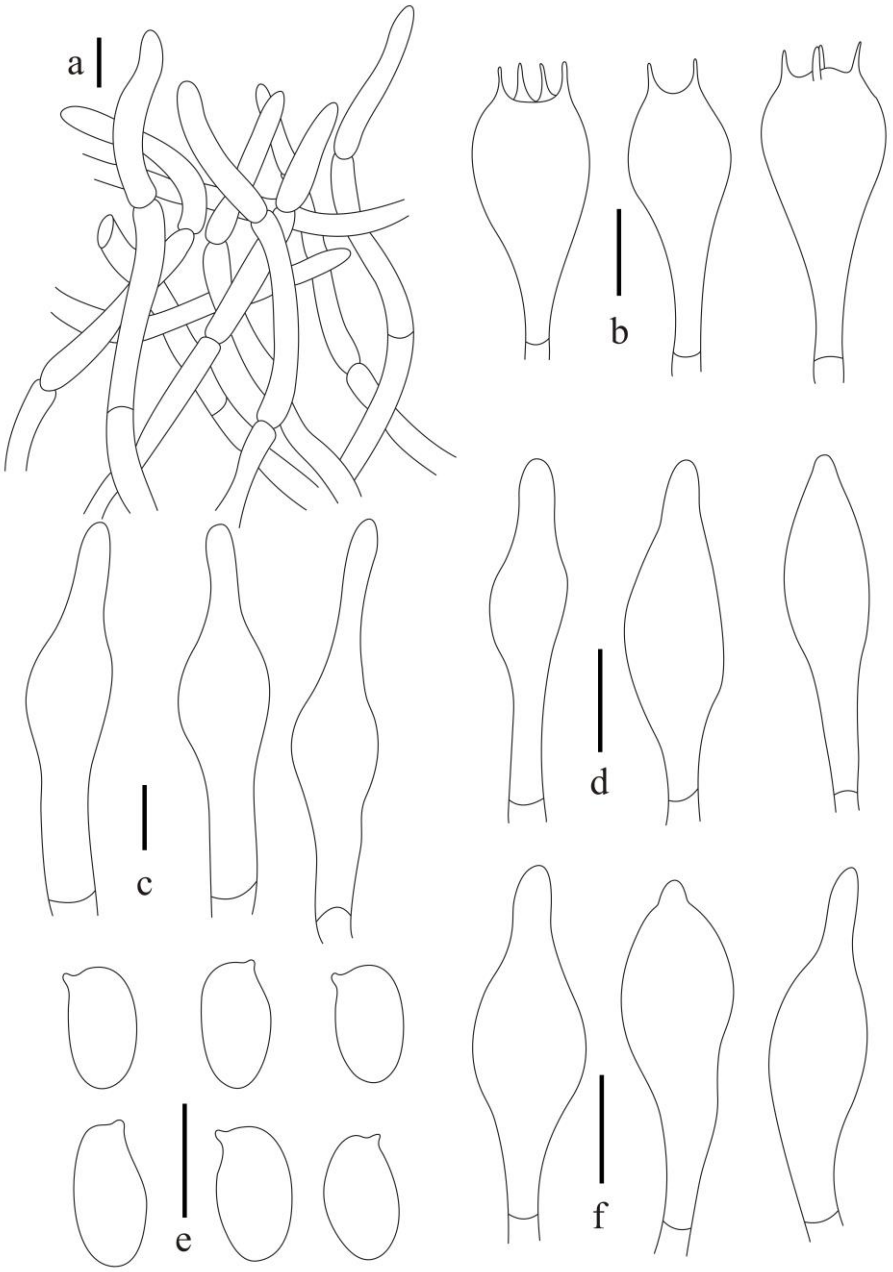

Figure 22 – *Suillellus olivaceus.* a Pileipellis. b Basidia. c Pleurocystidia. d Cheilocystidia. e Basidiospores. f Caulocystidia. Scale bars: a–f = 10 μm.

Basidiospores [120/2/3] (10.5–)11–13(–14) × 5.5–6.5(–7) μm, Q = 1.83–2.18, Q_{av} = 1.98 (± 0.13), subfusiform to fusiform in side view, sometimes with slight suprahilar depression, ellipsoid in face view, pale yellow to yellowish brown in water or 5% KOH, smooth. Basidia 30–42 × 11–15 μm, clavate, 4-spored, occasionally 2-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 4–10 μm wide. Cheilocystidia 29–45×7–10 μm, narrowly lageniform to lageniform, thin-walled. Pleurocystidia 38–75 × 6–15 μm, similar to cheilocystidia in shape, thin-walled. Pileipellis an interwoven trichoderm, composed of more or less vertically arranged thin-walled, hyaline or pale brown hyphae 3–9 μm in diam, terminal cells 14–42 × 4–9, subcylindrical, sometimes with subacute apex. Stipitipellis a hymeniform, with caulocystidia 30–55×8–20 μm, fusoid to lageniform, thin-walled. Stipe trama composed of parallel hyphae 4–11 μm wide. Clamp connections are absent.

Ecology and habitat – Solitary, scattered or in group on the ground in broadleaf forest dominated by *Quercus* spp., currently only known from Shanxi Province, northern China.

Other specimens examined – China, Shanxi Province, Jincheng City, Qinshui County, Lishan Mountains, on the ground in broad leaved forest dominated by *Quercus* sp., 1650 m elev, 25 July 2021, J.C. Lv, LJC026 (BJTC FM1765); *ibid*., Shangchuan Village, on the ground in broad leaved forest dominated by *Quercus* sp., 1733.5 m elev, 11 August 2022, N. Mao, MNM595 (BJTC FM2285); Pu County, Wulushan Mountains, on the ground in broad leaved forest dominated by *Quercus* sp., 1550 m elev, 28 July 2021, N. Mao, MNM274 (BJTC FM1874); *ibid*, 1470 m elev, 8 August 2022, J.C. Lv, LJC125 (BJTC FM2128); *ibid*, 14 August 2022, J.C. Lv, LJC284 (BJTC FM2411).

Note – *Suillellus olivaceus* is characterized by its rust reddish to olive green pileus, orange-yellow to scarlet red hymenophore, and stipe covered with distinct reticula. Phylogenetically, *Su. luridus*, a well-known species originally described from Europe, is related to *Su. olivaceus*. Morphologically it is differentiated from *Su. olivaceus* by its yellowish to reddish context and pileus that is brown or yellow-brown and rarely with olive tones (Schaeffer 1774, Vizzini et al. 2014). *Suillellus comptus* is somewhat similar to *Su. olivaceus*. Both species have red-orange, orange, yellowish-orange hymenophore and pileal context turning blue quickly when exposed. However, *Su. comptus* is easily distinguished from *Su. olivaceus* by its yellow to yellowish stipe (never red as frequently occur in *Su. olivaceus*) and poor reticulations on stipe surface (Vizzini et al. 2014). Although *Su. longitudinalis* and *Su. lacrymibasidiatus* are also distributed in China, both species are easily distinguished from *Su. olivaceu* by their brown pore surface that lacking the bright yellow and/or red tones (Wang et al. 2022).

Suillellus subamygdalinus Kuan Zhao & Zhu L. Yang, in Wu, Li, Zhu, Zhao, Han, Cui, Li, Xu & Yang, Fungal Diversity 81: 130 (2016) Figs 21a, 23

MycoBank number: MB 818474; Facesoffungi number: FoF 15016

Basidiomata medium sized. Pileus 102–120 mm diam; broadly convex applanate; surface dry, finely tomentose, soil red (#c88170), with a yellowish grey (#a59a7c) tone in the central part; context up to 17 mm thick, pale yellow (#f6ecc0), turning blue (#a2bbcd) quickly when exposed. Hymenophore tubulose, adnate, sometimes depressed around apex of stipe; surface orange-red (#883805), turning dark blue (#383864) quickly when exposed; tubes bright yellow (#f5e195); pores roundish, 0.35–0.6 mm diam. Stipe 70–90 × 22–25 mm, central, cylindrical to subcylindrical, solid, slightly enlarge downwards, yellowish red (#9b6042); surface covered with longitudinal reticula all over the stipe; context yellow with brown (#f6dcac) tone, turning blue (#93b8ca) when exposed. Basal mycelium white (#ffffff). Odor and taste are not recorded.

Basidiospores [60/1/2] 12–14 × 5–6 μm, Q = 2–2.55, Q_{av} = 2.25 (± 0.14), subfusiform in side view, with slight suprahilar depression, oblong to subfusoid in face view, pale yellow to yellowish brown in water or 5% KOH, smooth. Basidia 26–35 × 12–13 μm, clavate, 4-spored, occasionally 2-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 3–8 μm wide. Cheilocystidia 45–60 × 9–15 μm, narrowly lageniform to lageniform, thin-walled. Pleurocystidia similar to cheilocystidia in shape

and size. Pileipellis an interwoven trichoderm, composed of more or less vertically arranged thin-walled, hyaline or pale brown hyphae 3–7 μm in diam., terminal cells 14–51 × 4–7, subcylindrical, sometimes with subacute apex. Stipitipellis a hymeniform, with caulocystidia 30–45×12–20 μm, lageniform, thin-walled. Clamp connections are absent.

Ecology and habitat – Solitary, scattered or in group on the ground in broadleaf forest, and coniferous and broadleaf mixed forest, currently only known from China.

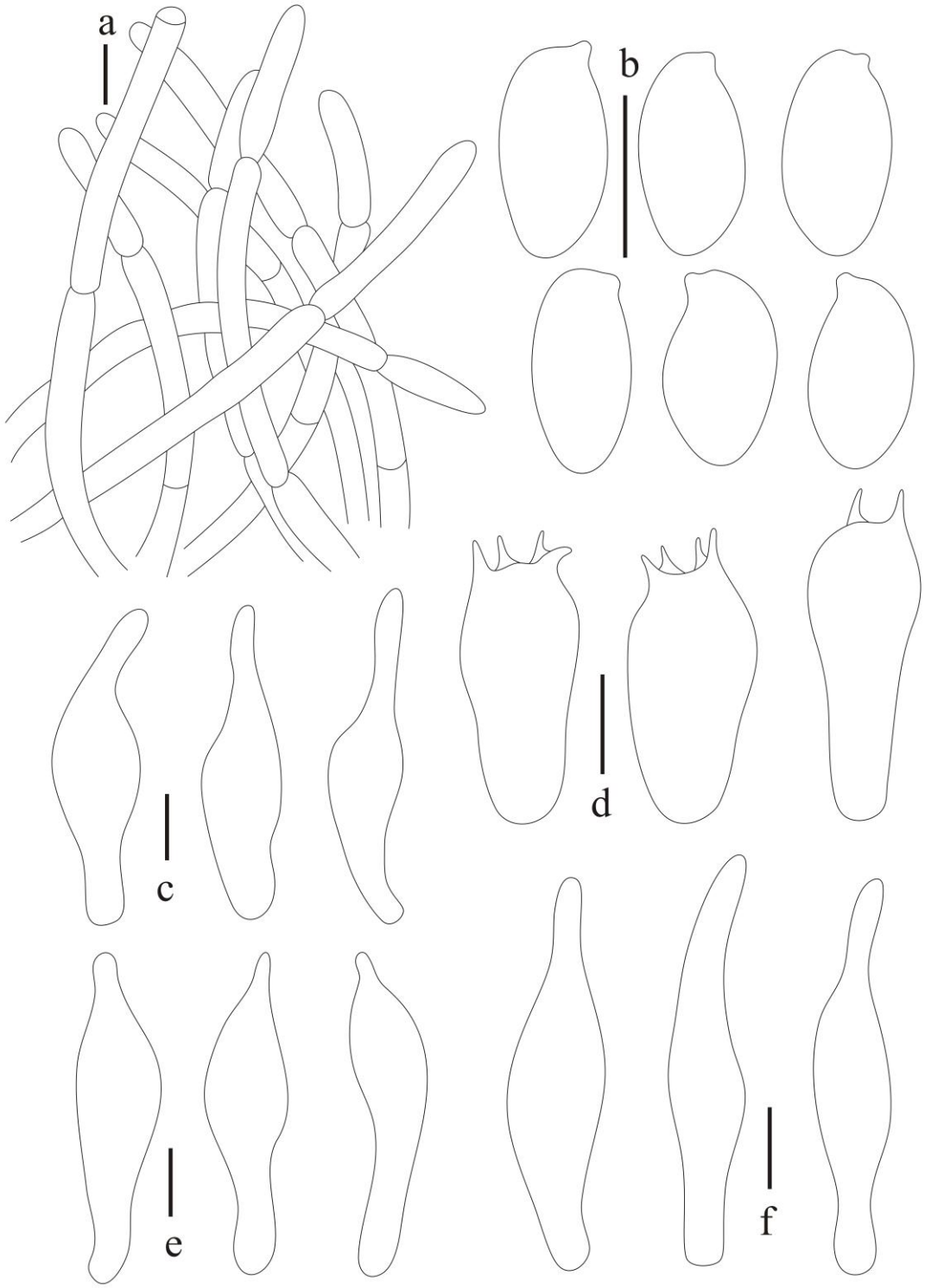

Figure 23 – *Suillellus subamygdalinus*. a Pileipellis. b Basidiospores. c Cheilocystidia. d Basidia. e Caulocystidia. f Pleurocystidia. Scale bars: a–d = 10 μm.

Specimens examined – China, Shanxi Province, Lvliang City, Jiaocheng County, Pangquangou, Guandi Mountains, on the ground in broad leaved forest dominated by *Populus* sp., 1875 m elev, 25 August 2022, N. Mao, MNM781 (BJTC FM2576).

Note – *Suillellus subamygdalinus* is characterized by its basidiomata turning blue tone when exposed, soil red pileus, and reticulate stipe (Wu et al. 2016a). *Suillellus amygdalinus* and *Su. pinophilus* are morphologically similar. However, *Su. amygdalinus* differs from *Su. subamygdalinus* by its stipe without distinct reticulations (Thiers 1975), *Su. pinophilus* by its relatively smaller basidiospores (9–12 × 5–6 μm) and basidia (18–27.5 × 10–13.5 μm) and conifer habitat (Wu et al. 2023). Rare, distributed in subalpine region under *Populus* sp. in Shanxi Province.

Suillellus yunnanensis G. Wu & Zhu L. Yang, in Wu G, Li H-J, Horak E, Wu K, Li G-M, and Yang Z-L, Mycosphere 14(1): 767 (2023) Figs 16j–l, 24

MycoBank number: MB 847063; Facesoffungi number: FoF 14144

Basidiomata small to medium-sized. Pileus 23–76 mm diam; convex, broadly convex to applanate; surface tomentose, pale yellow-brown (#d69b4b), orange-brown (#9c6f49), orange-red (#a5673e) to reddish brown (#c79063), sometimes olive brown (#b2a387); context up to 15 mm, yellow (#fff8c2), turning blue (#add2e5) quickly when exposed. Hymenophore tubulose, depressed around apex of stipe; surface brown (#af7c68), turning dark blue (#293846) quickly when exposed; tubes bright yellow (#e2e8c2), up to 8 mm long; pores roundish, 0.3–0.5 mm diam. Stipe 35–89 × 10–19 mm, central, cylindrical to subcylindrical, solid, equal, orange-brown (#c6785a) to purplish red (#965455); surface covered with longitudinal reticula all over the stipe; context pale yellow (#fdfbef), turning blue (#b4dbf6) quickly when exposed. Basal mycelium white. Odor and taste are not recorded.

Basidiospores [60/2/3] (12–)13–15 × (4–)4.5–6 μm, Q = 2.33–3.1, Q_{av} = 2.76 (± 0.24), subfusiform to fusiform in side view, sometimes with slight suprahilar depression, subfusoid in face view, pale yellow to yellowish brown in water or 5% KOH, smooth. Basidia 30–39 × 11–13.5 μm, clavate, 4-spored, occasionally 2-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 4–8 μm wide. Cheilocystidia (25–)31–50 × (5.5–)6–8 μm, narrowly lageniform to lageniform, thin-walled. Pleurocystidia 40–68 × 7–11 μm, similar to cheilocystidia in shape, thin-walled. Pileipellis an interwoven trichoderm, composed of more or less vertically arranged thin-walled, hyaline or pale brown hyphae 3–8 μm in diam, terminal cells 17–43 × 4–8 μm, subcylindrical. Stipitipellis a hymeniform, with caulocystidia 27–57 × 10–16.5 μm, fusoid to lageniform, thin-walled. Stipe trama composed of parallel hyphae 4–8 μm wide. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest dominated by *Quercus* spp., currently known from Shanxi Province, northern China and Yunnan Province Southwest China.

Specimens examined – China, Shanxi Province, Jincheng City, Qinshui County, Tuwo Township, Shangwoquan Village, on the ground in broad leaved forest dominated by *Quercus* sp., 1168 m elev, 25 August 2020, H. Liu, LH1082 (BJTC FM1064); *ibid*., 1090 elev, 21 July 2021, J.C. Lv, LJC044 (BJTC FM1814). Pu County, Wulushan Mountains, on the ground in broad leaved forest dominated by *Quercus* sp., 1820 m elev, 13 August 2022, J.C. Lv, LJC248 (BJTC FM2337); *ibid*., on the ground in broad leaved forest dominated by Quercus sp., 1820 m elev, 13 August 2022, J.C. Lv, LJC245 (holotype BJTC FM2334).

Note – *Suillellus yunnanensis* is characterized by its pileus with brown to olive brown tones, brown hymenophore, stipe covered with longitudinal reticula, and context bluing quickly when exposed. Three collections from Shanxi Province matched this species (Fig. 1). Our material is morphologically slightly different from the Yunnan Province material, with relatively narrower basidiospores (Q_{av} = 2.76 in our material, Q_{av} = 2.24 in Yunnan Province material) and relatively shorter basidia (30–39 × 11–13.5 μm in our our material, 34–62 (70) × 8–14 μm in Yunnan Province material). Phylogenetically, *Su. amygdalinus* and *Su. mendax* are closely related to *Su.*

yunnanensis (Fig. 1). However, *Su*. *amygdalinus* can be differentiated by its stipe surface without reticula (Bessette et al. 2000); *Su*. *mendax* mainly by its bright yellow to red hymenophore surface, and reticulum that appear the upper part of the stipe and rarely cover whole the stipe (Vizzini et al. 2014). *Suillellus subamygdalinus*, a species recently discovered in Shanxi Province, is somewhat similar to *Su*. *yunnanensis*. Both species have stipe with reticulum and pileal context turning blue quickly when exposed, but *Su*. *subamygdalinus* differs from *Su*. *yunnanensis* by its dull bread red or soil red pileus, orange-red to brownish red hymenophore surface, and broader basidiospores (Q_{av} = 2.29 ± 0.21) (Wu et al. 2016a).

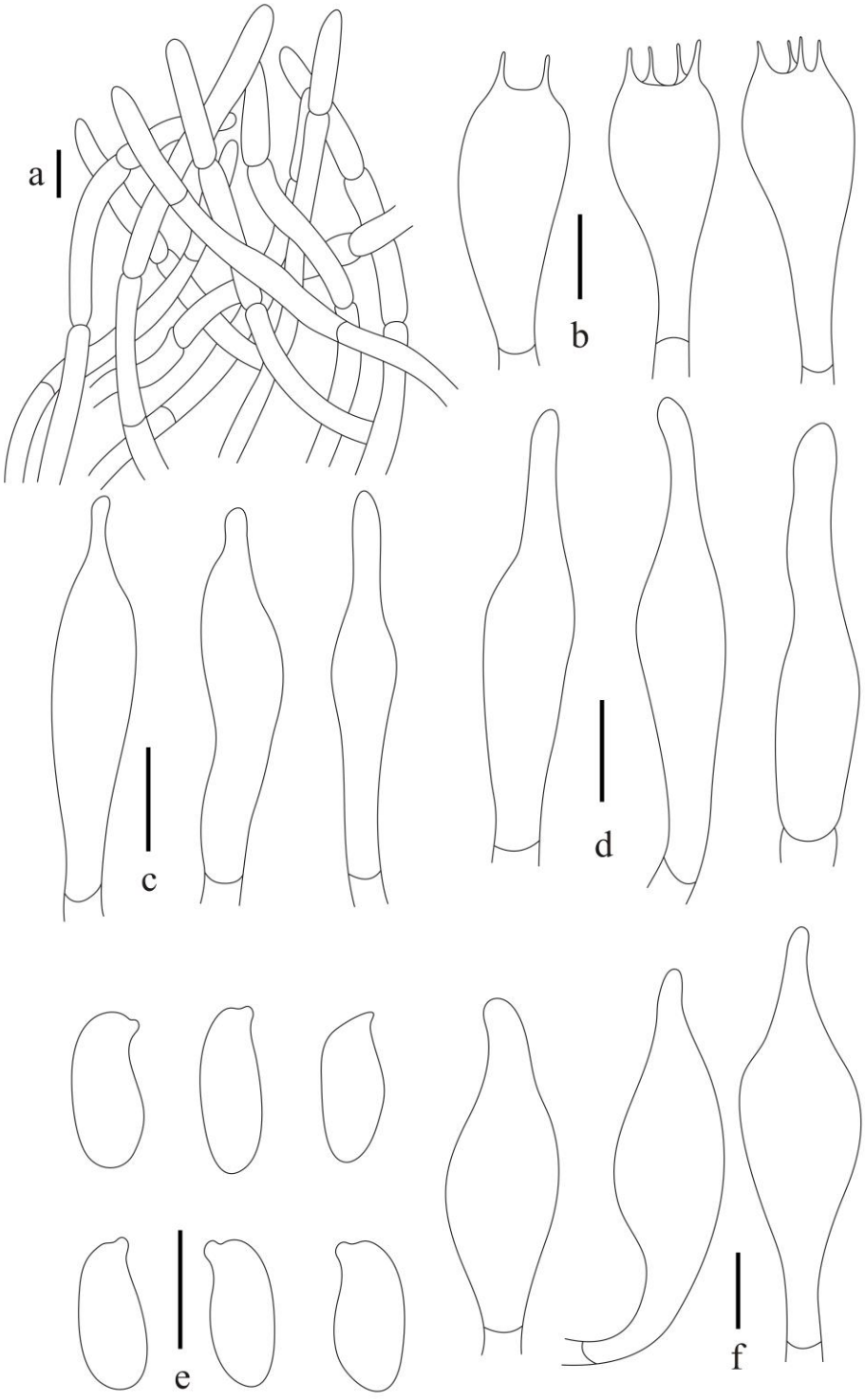

Figure 24 – *Suillellus yunnanensis.* a Pileipellis. b Basidia. c Cheilocystidia. d Pleurocystidia. e Basidiospores. f Caulocystidia. Scale bars: a–f = 10 μm.

Tylopilus P. Karst., Revue mycol., Toulouse 3(no. 9): 16 (1881)

MycoBank number: MB 18700; Facesoffungi number: FoF 14997

Notes – *Tylopilus* was established to accommodate *Boletus felleus* Bull. and its allies. This genus is characterized by white to greyish hymenophore surface turning flesh pink to purple-brown when mature, pileal context and stipe context unchanging in color, or turning rufescent in some species when exposed, and bitter taste (Wu et al. 2016a, Li & Yang 2021). A total of 32 species of *Tylopilus* are currently recorded in China, i.e. *T. albopurpureus* Yan C. Li & Zhu L. Yang, *T. alpinus* Yan C. Li & Zhu L. Yang, *T. argillaceus* Hongo, *T. atripurpureus* (Corner) E. Horak, *T. atroviolaceobrunneus* Yan C. Li & Zhu L. Yang, *T. aurantiacus* Yan C. Li & Zhu L. Yang, *T. brunneirubens* (Corner) Watling & E. Turnbull, *T. castanoides* Har. Takah., *T. felleus* (Bull.) P. Karst., *T. fuligineoviolaceus* Har. Takah., *T. fuscatus* (Corner) Yan C. Li & Zhu L. Yang, *T. griseipurpureus* (Corner) E. Horak, *T. griseiviridus* Yan C. Li & Zhu L. Yang, *T. griseolus* Yan C. Li & Zhu L. Yang, *T. himalayanus* D. Chakr., K. Das & Vizzini, *T. jiangxiensis* Kuan Zhao & Yan C. Li, *T. neofelleus* Hongo, *T. obscureviolaceus* Har. Takah., *T. olivaceobrunneus* Yan C. Li & Zhu L. Yang, *T. otsuensis* Hongo, *T. phaeoruber* Yan C. Li & Zhu L. Yang, *T. plumbeoviolaceoides* T.H. Li, B. Song & Y.H. Shen, *T. pseudoalpinus* Yan C. Li & Zhu L. Yang, *T. pseudoballoui* D. Chakr., K. Das & Vizzini, *T. purpureorubens* Yan C. Li & Zhu L. Yang, *T. rubrotinctus* Yan C. Li & Zhu L. Yang, *T. rufobrunneus* Yan C. Li & Zhu L. Yang, *T. subotsuensis* T.H.G. Pham, A.V. Alexandrova & O.V. Morozova, *T. vinaceipallidus* T.H. Li & Watling, *T. violaceobrunneus* Yan C. Li & Zhu L. Yang, *T. violaceorubrus* Yan C. Li & Zhu L. Yang, and *T. virescens* (Har. Takah. & Taneyama) N.K. Zeng, H. Chai & Zhi Q. Liang (Li & Yang 2021). In this paper, a known species discovered from Shanxi Province of northern China is documented as follows.

Tylopilus himalayanus D. Chakr., K. Das & Vizzini, in Chakraborty, Vizzini & Das, MycoKeys 33: 109 (2018) Figs 21b, 25

MycoBank number: MB 823975; Facesoffungi number: FoF 15017

Basidioma medium-sized. Pileus 116 mm diam, applanate; surface dry, tomentose, yellowish brown (#ab8d70); context up to 17 mm thick, solid, white (#c8dfee), unchanging in color when exposed. Hymenophore tubulose, adnate, surface dingy pink (#af878d), turning greyish brown (#d4ae8f) when exposed; tubes concolorous with hymenophore surface, up to 5 mm long; pores angular or subround. Stipe 9.5 × 18 mm, central, cylindrical, solid, enlarged downwards, brown (#978778) to reddish brown (#5a3e2a); surface smooth; context white (#d4dfdc), turning dark orange with 5% KOH. Basal mycelium white (#ffffff). Taste bitter.

Basidiospores [40/1/1] 11–14 × 3.5–4.5 μm, Q = 2.67–3.25, Q_{av} = 2.99 (± 0.21), subcylindrical to subfusiform with slight suprahilar depression, yellowish in water or 5% KOH, smooth. Basidia 23–31 × 7.5–9 μm, clavate, hyaline to yellowish in water or 5% KOH, 4-spored, occasionally 2- or 3-spored. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 3–8 μm wide. Cheilocystidia 35–60 × 8–12 μm, fusiform to fusoid-ventricose, yellowish to brownish yellow in 5% KOH, thin-walled, smooth. Pleurocystidia similar to cheilocystidia in shape and size. Pileipellis a palisadoderm, composed of interwoven hyphae 4–12 μm wide, smooth, thin-walled, always with pale brown to pale yellow extracellular pigments. Stipitipellis a cutis, composed of sub-parallel hyphae 4–10 μm wide, caulocystidia not observed. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest or coniferous and broadleaf forest mixed forest, currently known in China and India.

Specimens examined – China, Shanxi Province, Yuncheng City, Xia County, Sijiao Town, on the ground in pine and oak mixed forest, 1363 m elev, 12 Aug. 2022, N. Mao, MNM611 (BJTC FM2315).

Note – *Tylopilus himalayanus* (Figs 1, 21b) is characterized by its brown tone pileus, stipe without reticulum or rarely with a faint reticulum restricted to the very apex, and medium sized (10.9–14.4 × 3.9–4.9 μm) basidiospores (Chakraborty et al. 2018). *Tylopilus olivaceobrunneus*,

a species recently described from Anhui Province in eastern China, is similar morphologically. However, *T. olivaceobrunneus* can be distinguished by its relatively small basidiospores (9–11 × 3–3.5 μm) and trichoderm pileipellis (Li & Yang 2021). Rare, only known from central area in Zhongtiao Mts. in Shanxi Province.

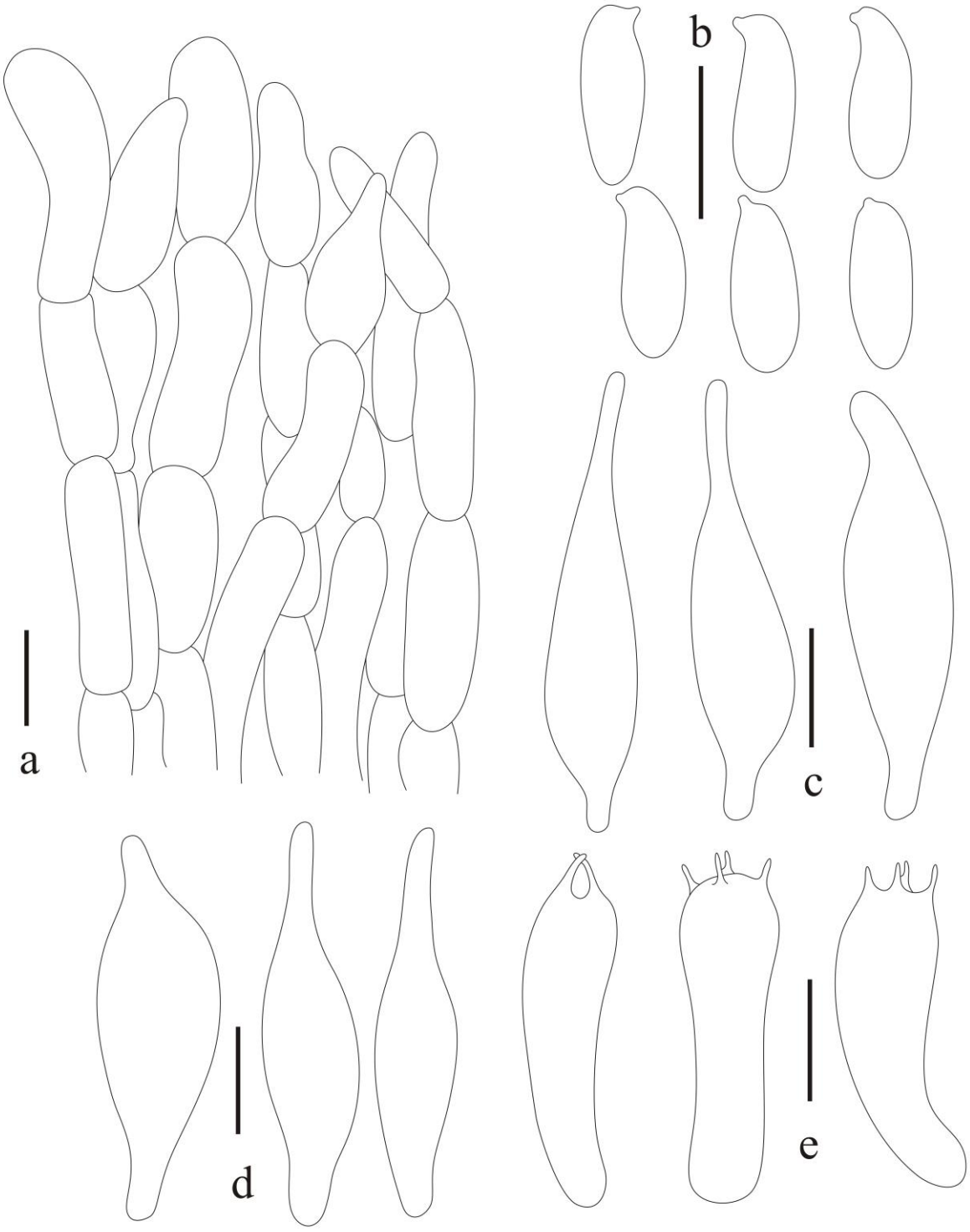

Figure 25 – *Tylopilus himalayanus*. a Pileipellis. b Basidiospores. c Cheilocystidia. d Pleurocystidia. e Basidia. Scale bars: a–d = 10 μm.

Villoboletus L. Fan & N. Mao, in Mao, Zhao, Xu & Fan, Mycologia: 3 (2023)
MycoBank number: MB 846404; Facesoffungi number: FoF 14998

Notes – *Villoboletus* is a recently established genus, which is found in Shanxi Province of northern China and only includes *V. persicinus.* Morphologically, this genus is characterized by stipe covered with densely flocculent hairs, yellowish basidiospores (Mao et al. 2023).

Villoboletus persicinus L. Fan & N. Mao, in Mao, Zhao, Xu & Fan, Mycologia: 1–8 (2023)

Figs 21c, 26

MycoBank number: MB 846406; Facesoffungi number: FoF 15018

Basidiomata small to medium-sized to large. Pileus 20–90 mm diam; convex at a young age, then broadly convex, sometimes with wavy margin; margin decurved; surface dry, pale pink (f7c4c8) to pink (f4adb3), finely pubescent; context up to 11 mm thick, solid, white (ffffff), cream white (fffffe) to yellowish white (ffffeb), turning pale blue (afeeee) to blue (85b6e5) slowly when exposed. Hymenophore tubulose, adnate to decurrent, surface bright yellow (ffffb1) at a young age, then orange (ffba3b) or pale reddish (ffa808) with age, turning greenish blue (7cfff1) quickly when bruised; tubes concolorous with hymenophore surface, 5–8 mm long; pores angular or round, 0.5–1.5 mm diam. Stipe 30–70 × 8–20 mm, central, cylindrical to subcylindrical, solid, firm, background yellowish white (fff7cd) at apex, pale pink (f7c4c8) to pinkish red (ff8da1) downward, surface covered with plenty of flocculent hairs from the apex to just above the base, without flocculent hairs near the pileus. Context in stipe firm, yellowish white (ffffeb), turning purplish red (ff0080) from bottom up with age and turning blue (85b6e5) to dark blue when exposed. Basal mycelium whitish. Odor and taste are not recorded.

Basidiospores [60/3/3] (10–)12–14(–16) × (4.8–)5–6(–6.5) μm, Q = 2–2.7, Q_{av} = 2.39 (± 0.15), fusiform, ellipsoid-fusiform to subfusiform in side view, ellipsoid-fusiform to subfusiform, occasionally elongated-ellipsoid in face view, pale yellow to honey yellow, smooth, thin-walled. Basidia 27–40 × 10.5–13 μm, narrowly clavate or clavate, rarely broadly clavate, hyaline to yellowish in water and 5% KOH, thin-walled, 4-spored, occasionally 2- or 3-spored, sterigmata 2–5 μm long. Hymenophoral trama boletoid-type, that is divergent, with distinct mediostratum and loosely arranged lateral strata, hyphae cylindrical, 3.5–8 μm wide. Cheilocystidia 29–50 × 4–9 μm, mostly lageniform, fusoid-ventricose with subacute apex or long beak, occasionally conical, hyaline, thin-walled, smooth, without encrustation. Pleurocystidia 32–55 × 5–9 μm, similar to cheilocystidia in shape, hyaline, thin-walled, smooth, without encrustation. Caulocystidia absent. Pileipellis an intricate trichodermium, composed of 3.5–10 μm wide cylindrical to filamentous hyphae, loosely interwoven in clusters, with terminal cells 30–80 × 4–7 μm, which are almost subcylindrical, sometimes with subacute apex, pale pinkish-red in water and pale yellowish to bright yellow in 5% KOH. Stipitipellis 120–180 μm thick, slightly gelatinized, composed of 3–10 μm wide cylindrical to filamentous hyphae, loosely interwoven, colorless or pale yellow in water and 5% KOH, terminal cells of hyphae 30–70 × 3–8 μm. Stipe trama composed of parallel hyphae 4–8.5 μm wide, colorless in water and 5% KOH. Clamp connections are absent.

Ecology and habitat – Solitary, scattered, or gregarious on the ground in broadleaf forest dominated by *Quercus* sp., 1500–1600 m elev, currently only known from Shanxi Province, northern China.

Specimens examined – China, Shanxi Province, Pu County, Wulushan Mountains, 1550 m elev, on the ground in broadleaf forest dominated by Quercus sp., 28 Jul 2021, N. Mao, MNM268 (holotype BJTC FM1869); *ibid*. N. Mao, MNM396 (BJTC FM1904); *ibid*. N. Mao, MNM398 (BJTC FM1906); *ibid*. 24 Aug 2022, N. Mao, MNM680 (BJTC FM2439).

Note – *Villoboletus persicinus* is characterized by its basidiomata turning blue when exposed, pileus covered with finely pubescent, stipe surface covered with plenty of flocculent hairs. This species is recently introduced from Shanxi Province and is one of the frequently encountered boletoid fungus in central area under oaks in Shanxi Province, and probably native to this province (Mao et al. 2023). *Butyriboletus regius* (Krombh.) D. Arora & J.L. Frank is similar to *V. persicinus* in pink pileus and bright yellow hymenophore surface turning blue when bruised. However, *Bu. regius* is differs from *V. persicinus* by its stipe covered with reticula (Janda et al. 2019).

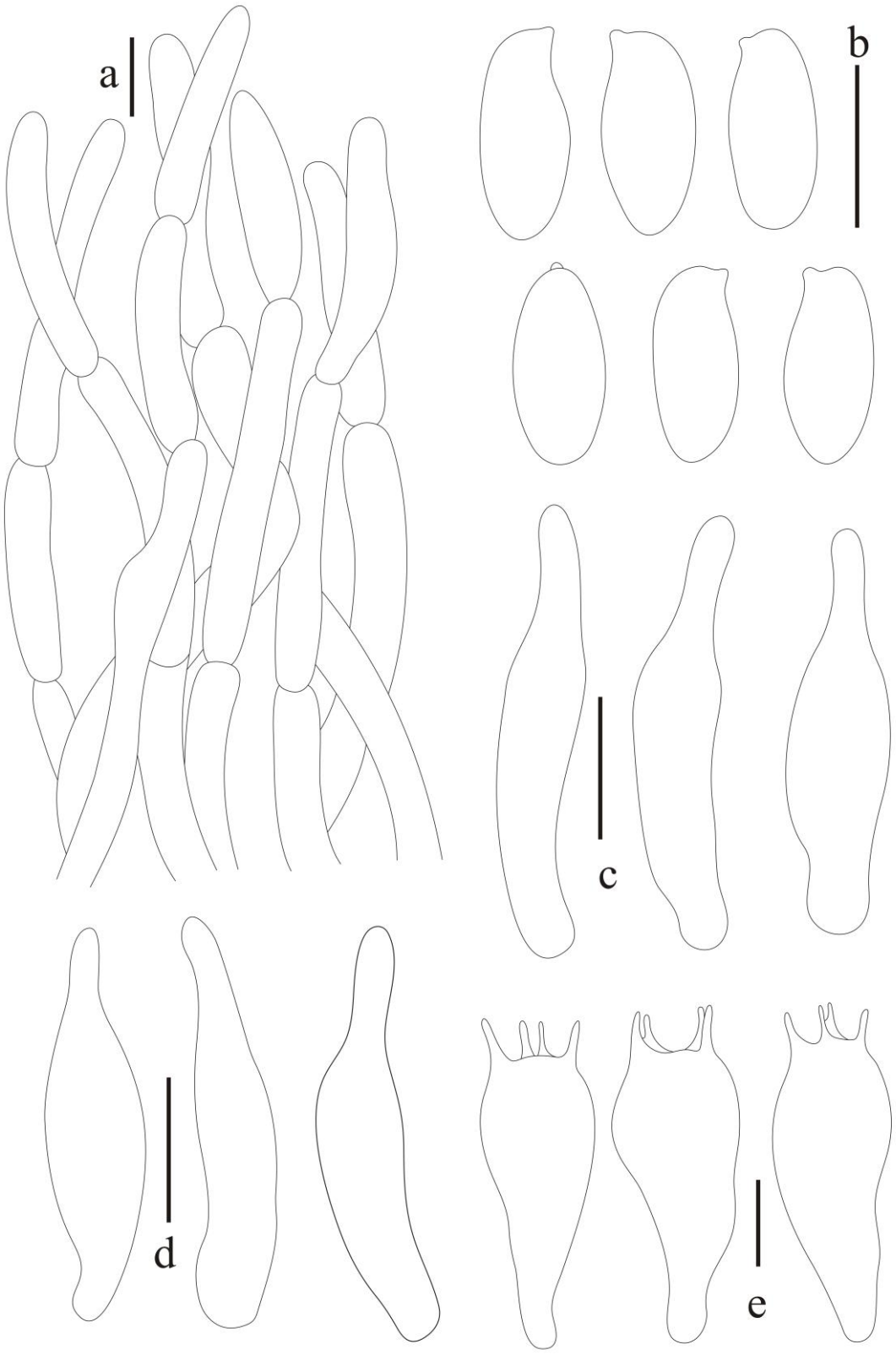

Figure 26 – *Villoboletus persicinus*. a Pileipellis. b Basidiospores. c Basidia. c Cheilocystidia. d Pleurocystidia. e Basidia. Scale bars: a–d = 10 μm.

Xerocomus Quél., in Mougeot & Ferry, Fl. Vosges, Champ.: 477 [109 repr.] (1887)

MycoBank number: MB 18763; Facesoffungi number: FoF 14999

Notes – *Xerocomus* was established to accommodate *Boletus subtomentosus* L. and its allies. The genus is morphologically characterized by its pileus with brown tones, yellowish, flesh yellow

to brownish yellow hymenophore, turning blue when exposed, relatively large pores, and trichodermium pileipellis (Wu et al. 2016a, Gelardi et al. 2023). There are about 120 species accepted for this genus according to He et al. (2019), six of which are recorded in China, i.e. *X. microcarpoides* (Corner) E. Horak, *X. piceicola* M. Zang & M.S. Yuan, *X. puniceiporus* T.H. Li, Ming Zhang & T. Bau, *X. rugosellus* (W.F. Chiu) F.L. Tai, *X. subparvus* Xue T. Zhu & Zhu L. Yang, and *X. velutinus* Xue T. Zhu & Zhu L. Yang. In this paper, two new species and a known species discovered from Shanxi Province of northern China are documented as follows.

Xerocomus ferrugineus (Schaeff.) Alessio, Boletus Dill. ex L. (Saronno): 282 (1985)

Figs 21d, 27

MycoBank number: MB 129479; Facesoffungi number: FoF 15019

Basidiomata small to medium-sized. Pileus 19–55 mm diam; convex, broadly convex to applanate; surface dry, tomentose, sometimes forming concolorous erected scales, brown (#b59b7b) to dark brown (#b6937a), more or less with greenish tones; context up to 11 mm, white (#ffffff) to pale yellow (#f9f9cd), unchanging in color when exposed. Hymenophore tubulose, adnate; surface bright yellow (#ccc969), turning dark blue (#7c7b4c) when exposed; tubes concolorous with hymenophore surface, 3–6 mm long; pores angular, up to 2.5 mm diam. Stipe 27–69 × 2–9 mm, central, cylindrical to subcylindrical, solid, equal, pale yellow (#a7a082) at a young age, then pale brown (#a96831) to brown (#55371b) with age; surface covered with reticula on the upper part, reddish brown (#533a2c) scales over the stipe; context white (#ffffff) to pale yellow (#e2dcbc), unchanging in color when exposed. Basal mycelium yellow (#cdb369). Odor and taste are not recorded.

Basidiospores [100/2/5] (10–)12–15(–16.5) × 3.5–5 μm, Q = 2.8–3.5, Q_{av} = 3.15 (± 0.3), subfusiform to fusiform in side view, sometimes with slight suprahilar depression, subfusoid in face view, pale yellow to yellowish brown in water or 5% KOH, smooth. Basidia 30–40 × 9.5–11.5 μm, clavate, 4-spored, occasionally 2-spored, sterigmata up to 6 μm long. Hymenophoral trama between phylloporoid-type, that is divergent, with distinct mediostratum and densely arranged lateral strata, hyphae cylindrical, 3–8.5 μm wide. Cheilocystidia 38–73 × 7–13μm, clavate, fusoid to lageniform thin-walled. Pleurocystidia 35–93(–107) × 7.5–15 μm, similar to cheilocystidia in shape, thin-walled. Pileipellis an interwoven trichoderm, composed of more or less vertically arranged thin-walled, hyaline or pale brown hyphae; the terminal cells subcylindrical, 32–70 × 8–16 μm. Stipitipellis a hymeniform, with caulocystidia 26–48 × 10.5–18 μm, clavate to fusoid, thin-walled. Stipe trama composed of parallel hyphae 3–9 μm wide. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in coniferous or broadleaved forest, currently only known from China, Europe and North America.

Specimens examined – China, Shanxi Province, Jincheng City, Qinshui County, Lishan Mountains, on the ground in broadleaf forest dominated by Quercus sp., 15 July 2021, H. Liu, LH934 (BJTC FM1245); *ibid*., H. Liu, LH937 (BJTC FM1248); Pu County, Wulushan Mountains, on the ground in broadleaf forest dominated by Quercus sp., 1510 m elev, 28 July 2021, J.C. Lv, LJC079 (BJTC FM1845); *ibid*., 9 August 2022, J.C. Lv, LJC158 (BJTC FM2186); *ibid*., 1795 m elev, 13 August 2022, N. Mao, MNM636 (BJTC FM2369); Taiyuan City, Loufan County, Yunding Mountains, 1840 m elev, 23 August 2022, J.C. Lv, LJC328 (BJTC FM2465).

Note – *Xerocomus ferrugineus* is characterized by its brown to dark brown pileus, bright yellow hymenophore, and pale brown to brown stipe covered with reticula on the upper part, reddish brown scales over the stipe. This species is new to China. *Xerocomus ferrugineus* is a species originally described from Europe and also reported from North America (Taylor et al. 2006). Several collections from Shanxi Province matched this species (Figs 1, 14d). It is notable that the North American samples of '*X. ferrugineus*' cited in this study occupied a different position from the European ones in our analysis (Fig. 1), suggesting that they may represent a different species. *Xerocomus tenuistipitatus* and *X. ferrugineus* are easily confused, both species have dark brown pileus, bright yellow hymenophore, and stipe covered with reticula on the upper part.

However, *Xerocomus tenuistipitatus* has yellow basal mycelium, and small basidiospores ((10–)11–13(–13.5) × 4–5(–5.5) μm, Q = 2.2–3.0).

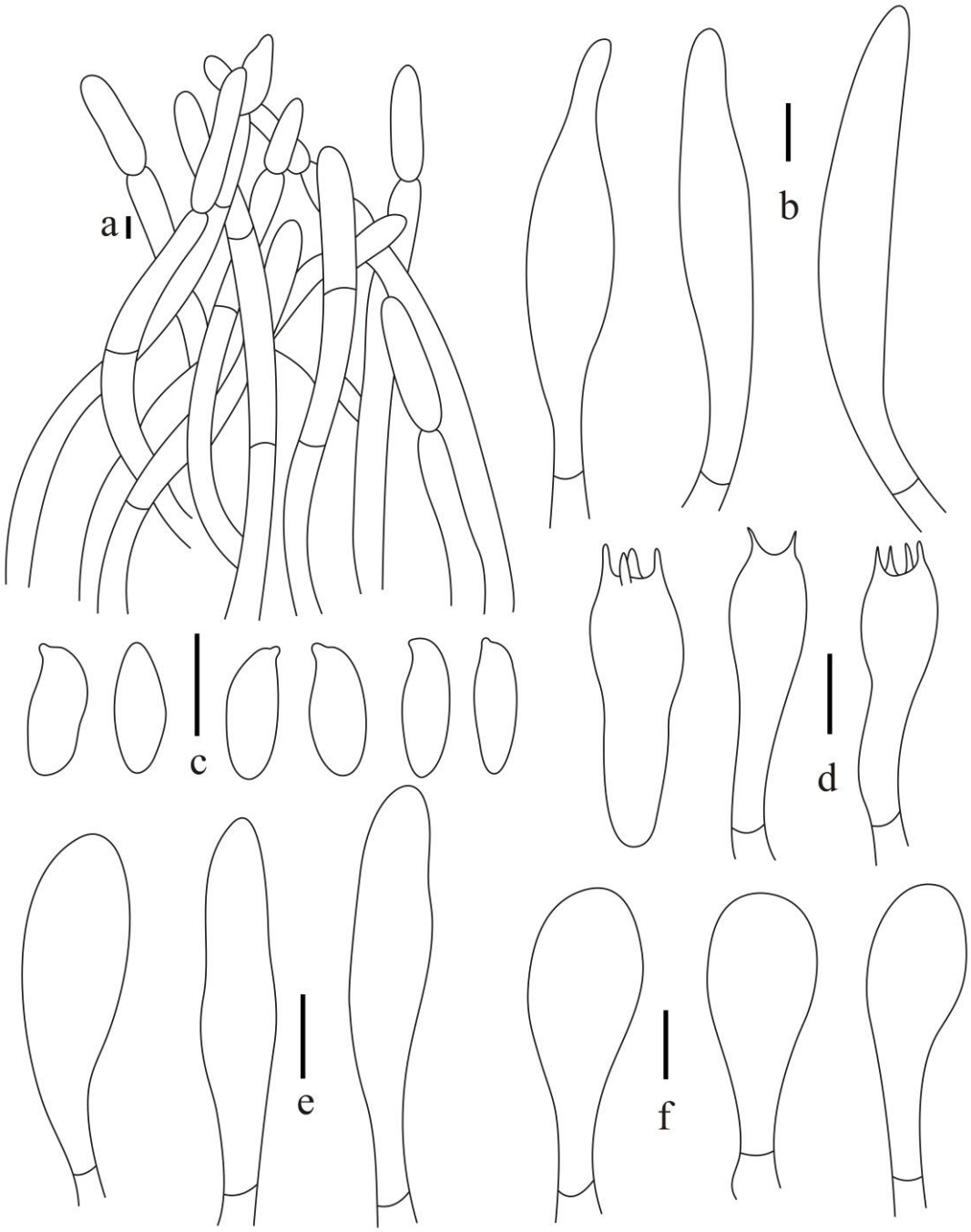

Figure 27 – *Xerocomus ferrugineus.* a Pileipellis. b Pleurocystidia. c Basidiospores. d Basidia. e Cheilocystidia. f Caulocystidia. Scale bars: a–f = 10 μm.

Xerocomus galbanus L. Fan, N. Mao & T.Y. Zhao, sp. nov. Figs 21e–f, 28

MycoBank number: MB 850268; Facesoffungi number: FoF 15020

Etymology – ***galbanus***, refers to the yellow-green color of hymenophore.

Typification – China, Shanxi Province, Jincheng City, Qinshui County, Tuwo Township, Shangwoquan Village, on the ground in coniferous and broad-leaved mixed forest dominated by *Pinus* sp. and *Quercus* sp., 1150 m elev, 26 July 2022, N. Mao, MNM367 (holotype BJTC FM1790). GenBank: ITS = OR655171; nrLSU = OR655217; *tef1* = OR660016; *rpb2* = OR659968.

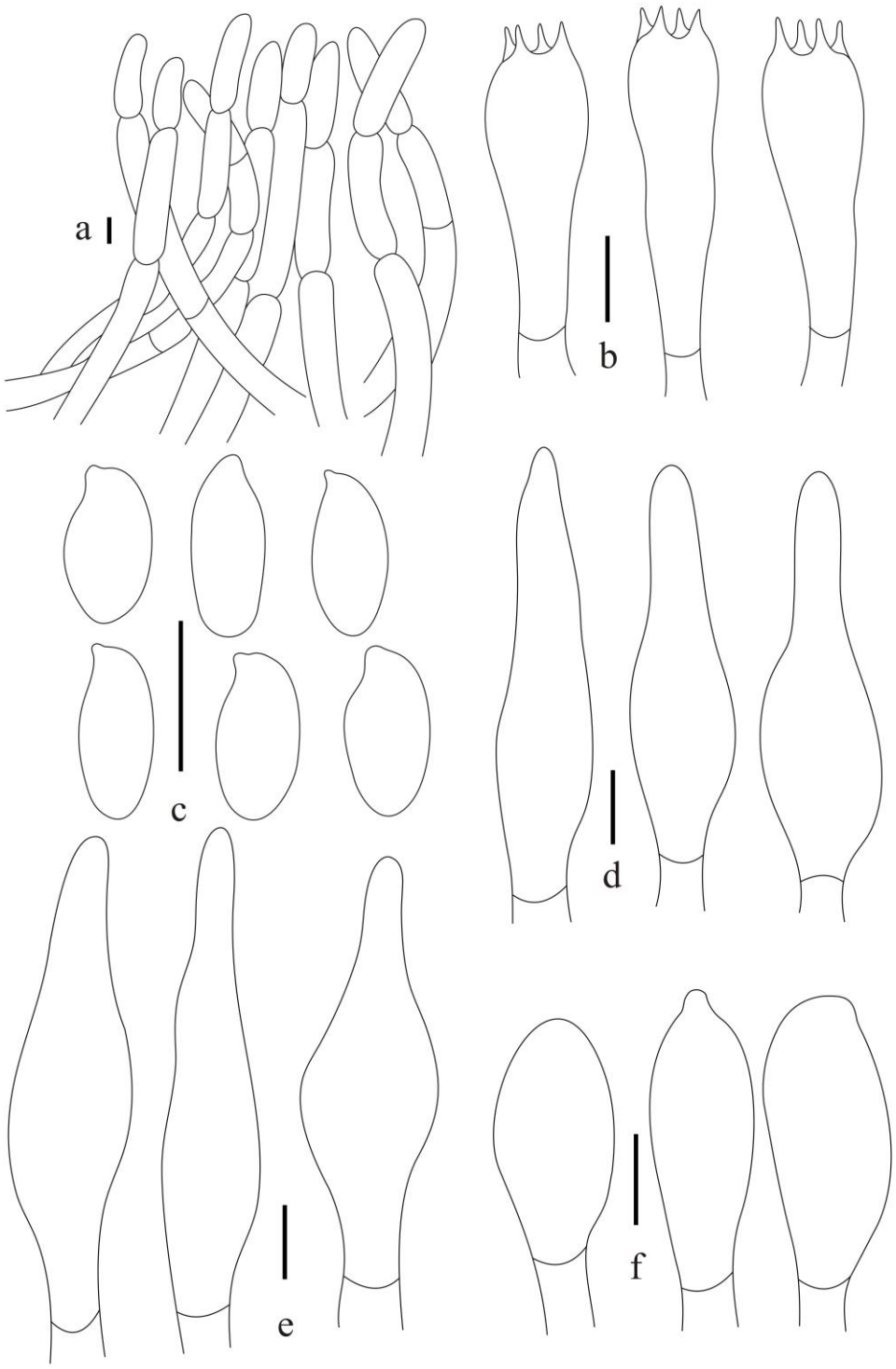

Figure 28 – *Xerocomus galbanus.* a Pileipellis. b Basidia. c Basidiospores. d Cheilocystidia. e Pleurocystidia. f Caulocystidia. Scale bars: a–e = 10 μm.

Basidiomata small to medium-sized. Pileus 23–76 mm diam; convex, broadly convex to applanate; surface dry, tomentose, sometimes cracked, greyish white (#eff0e9) to pale yellow-brown (#d7d1aa); context up to 9 mm, white (#e8efec) to pale yellow (#e9fdc6), unchanging in color when exposed. Hymenophore tubulose, adnate, sometimes depressed around apex of stipe; surface bright yellow-green (#f3e780), weakly turning blue (#5b8aab) when exposed; tubes concolorous with hymenophore surface, up to 8 mm long; pores angular, 1–2 mm diam. Stipe 55–95 × 3.5–10 mm, central, cylindrical to subcylindrical, solid, equal, pale yellow (#e7e1b4) at a young age, then pale brown (#d6bf91) to brown (#855424) with age, whitish towards the base;

surface covered with large and elongated reticula on the upper part; context white (#d0dbd8) to pale yellow (#d5ceaa), unchanging in color when exposed. Basal mycelium white. Odor and taste are not recorded.

Basidiospores [60/2/2] (12–)13–15 × (4–)4.5–6 μm, Q = 2.3–3.0, Q_{av} = 2.63 (± 0.26), subfusiform to fusiform in side view, sometimes with slight suprahilar depression, subfusoid in face view, pale yellow to yellowish brown in water or 5% KOH, smooth. Basidia 27–39.5 × 8–12 μm, clavate, 4-spored, occasionally 2-spored, sterigmata up to 6 μm long. Hymenophoral trama between phylloporoid-type, that is divergent, with distinct mediostratum and densely arranged lateral strata, hyphae cylindrical, 3–10 μm wide. Cheilocystidia 48–79 × 9.5–18 μm, clavate, fusoid to lageniform, thin-walled. Pleurocystidia similar to cheilocystidia in shape and size. Pileipellis an interwoven trichoderm, composed of more or less vertically arranged thin-walled, hyaline or pale brown hyphae; terminal cells subcylindrical, 29–55 × 9–16 μm. Stipitipellis a hymeniform, with caulocystidia 20–38 × 9–14 μm, clavate to fusoid, thin-walled. Clamp connections are absent.

Ecology and habitat – Solitary or scattered on the ground in coniferous and broad-leaved mixed forest dominated by *Pinus* sp. and *Quercus* sp., currently only known from Shanxi province, northern China.

Other specimens examined – China, Shanxi Province, Jincheng City, Qinshui County, Tuwo Township, Shangwoquan Village, on the ground in broadleaf forest dominated by *Quercus* sp., 1150 m elev, 26 July 2021, J.C. Lv, LJC043 (BJTC FM1813).

Note – *Xerocomus galbanus* is characterized by its greyish white to pale yellow-brown pileus, bright yellow-green hymenophore weakly turning blue when exposed, stipe covered with large and elongated reticula on the upper part, and context unchanging in color when exposed. *Xerocomus fulvipes*, a species found in Yunnan Province, southwestern China, was phylogenetically sister to *X. galbanus* (Fig. 1). Morphologically, *X. fulvipes* is distinguished from *X. galbanus* by its pale yellow-brown to pale red-brown pileus, pileal context staining bluish slowly or faintly bluish when exposed, and relatively smaller basidiospores (10–12 × 4–5 μm) (Wu et al. 2016a). *Xerocomus subtomentosus* is similar to *X. galbanus* in its yellow hymenophore turning blue when exposed. However, *X. subtomentosus* differs from the new species by its olive yellow pileus, stipe covered with tiny reddish granules, and European distribution (Alessio 1985).

Xerocomus tenuistipitatus L. Fan, N. Mao & T.Y. Zhao, sp. nov. Figs 21g–i, 29

MycoBank number: MB 850269; Facesoffungi number: FoF 15021

Etymology – ***tenuistipitatus***, refers to the thin stipe of basidiomata.

Typification – China, Shanxi Province, Jincheng City, Qinshui County, Shangchuan Village, on the ground in broadleaf forest dominated by *Quercus* sp., 1770 m elev, 11 August 2022, J.C. Lv, LJC203 (holotype BJTC FM2267). GenBank: nrLSU = OR655223; *tef1* = OR660022; *rpb2* = OR659973.

Basidiomata small to medium-sized. Pileus 31–70 mm diam; broadly convex to applanate; surface dry, pale brown (#e7ddc3) to wood brown (#e6bb89), sometimes forming concolorous erected scales, turning brown–reddish (#927351) when wet; context up to 9 mm, white (#fbffe7) to pale yellow (#feffcc), turning blue (#add3e6) when exposed. Hymenophore tubulose, adnate; surface bright yellow (#e4f066) at a young age, then yellowish brown (#c4b348) with age, turning dark blue (#596650) when exposed; tubes concolorous with hymenophore surface, 2–10 mm long; pores angular, up to 3 mm diam. Stipe 35–45 × 4–7 mm, central, cylindrical to subcylindrical, solid, equal, upper part concolorous with hymenophore, pale brown (#ceb78f) downwards; surface covered with reticula on the upper part; context white (#f4fffd) to pale yellow (#eef7ca), unchanging in color when exposed. Basal mycelium white. Odor and taste are not recorded.

Basidiospores [60/2/2] (10–)11–13(–13.5) × 4–5(–5.5) μm, Q = 2.2–3.0, Q_{av} = 2.58 (± 0.22), subfusiform to fusiform in side view, sometimes with slight suprahilar depression, subfusoid in face view, pale yellow to yellowish brown in water or 5% KOH, smooth. Basidia 28–39 × 9–15 μm, clavate, 4-spored, occasionally 2-spored. Hymenophoral trama between phylloporoid-type, that is divergent, with distinct mediostratum and densely arranged lateral strata, hyphae cylindrical, 4–9

μm wide. Cheilocystidia 38–67 × 9–17.5 μm, fusoid-ventricose to lageniform, with long beak, thin-walled. Pleurocystidia 52–75 × 11–18 μm, similar to cheilocystidia in shape, thin-walled. Pileipellis an interwoven trichoderm, composed of more or less vertically arranged thin-walled, hyaline or pale brown hyphae; the terminal cells subcylindrical, 14–44 × 10–15 μm. Stipitipellis a hymeniform, with caulocystidia 27–39 × 10–14 μm, clavate to fusoid, thin-walled. Stipe trama composed of parallel hyphae 5–10 μm wide. Clamp connections are absent.

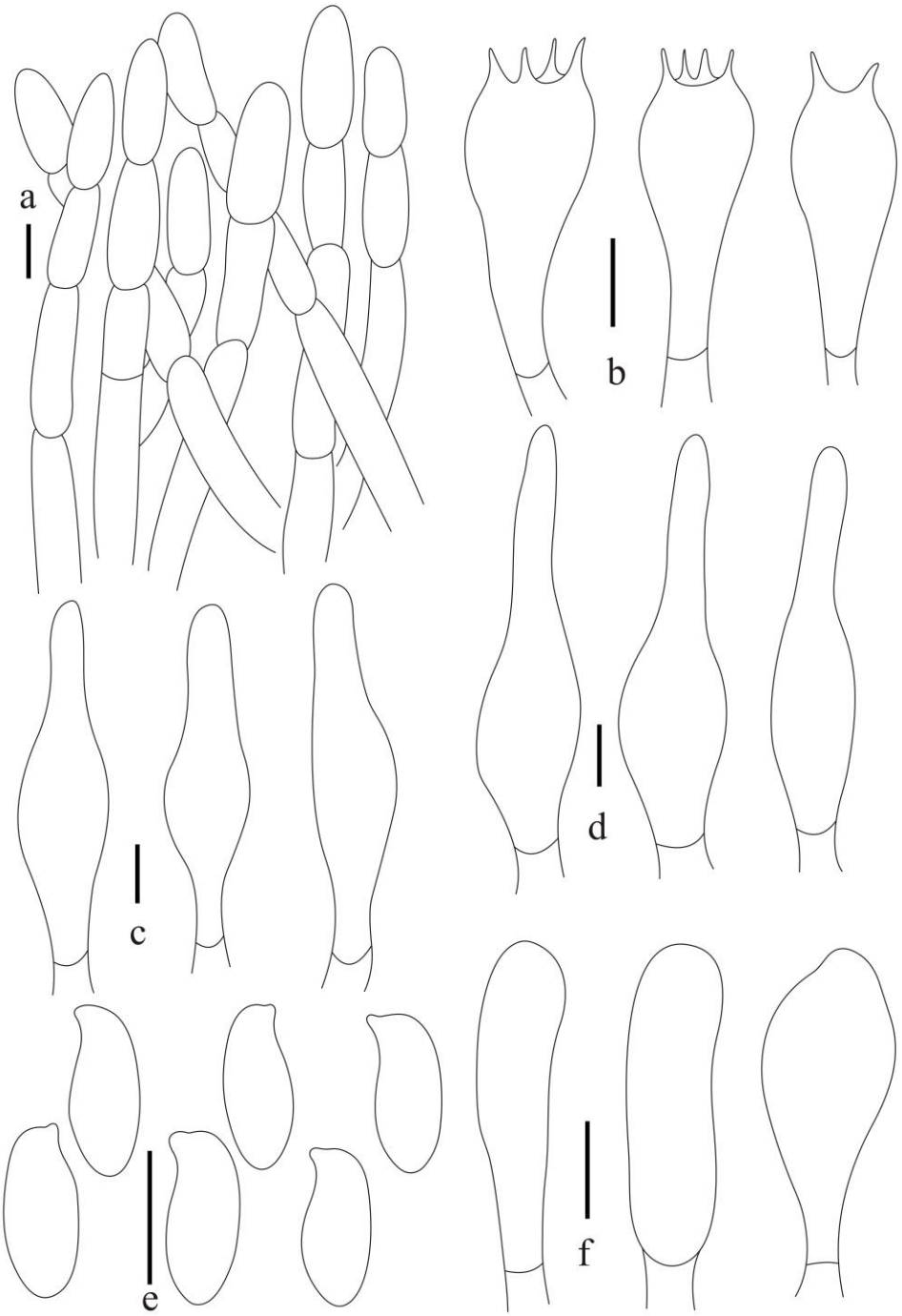

Figure 29 – *Xerocomus tenuistipitatus.* a Pileipellis. b Basidia. c Cheilocystidia. d Pleurocystidia. e Basidiospores. f Caulocystidia. Scale bars: a–f = 10 μm.

Ecology and habitat – Solitary or scattered on the ground in broadleaf forest dominated by *Quercus* sp., currently only known from Shanxi province, northern China.

Other specimens examined – China, Shanxi Province, Changzhi City, Qinyuan County, Lingkong Mountains, on the ground in broadleaf forest dominated by *Quercus* sp., 1460 m elev, 15 August 2022, N. Mao, MNM711 (BJTC FM2684).

Note – *Xerocomus tenuistipitatus* is characterized by its pale brown to wood brown pileus, sometimes covered with finely scales, pileal context turning blue when exposed, stipe thin (usually less than 10 mm diam) and covered with reticula on the upper part. The European *X. subtomentosus* is phylogenetically sister to *X. tenuistipitatus*, and the color of pileus in both the two species turn brown–reddish when wet. However, *X. subtomentosus* is distinguished from *X. tenuistipitatus* by its stipe that is 10–20 mm in diam, having longitudinally ribs and tiny reddish granules on surface, and sometimes turning blue when brusied (Alessio 1985, Taylor 2006). *Xerocomus galbanus* described in this study is somewhat similar to *X. tenuistipitatus*, which is also found in Shanxi Province and associated with *Quercus*. It is distinguished by its larger basidiospores of 13–15 × 4.5–6 μm (11–13 × 4–5 μm in *X. tenuistipitatus*), and hymenophore weakly blue when bruised (dark blue in *X. tenuistipitatus*).

Discussion

Boletaceae species reported from Shanxi Province before this study

There are 15 species of Boletaceae reported from Shanxi Province before this study. Three of them, *Bu. brunneoides*, *Bu. sinoregius* and *V. persicinus*, recently described by our group (Fu et al. 2022, Mao et al. 2023), have been confirmed in this study (Fig. 1). The remaining 12 species are all determined based on morphology alone, which are documented as follows.

Boletus edulis is reported from Qinshui County, southern Shanxi Province (Liu 1991). We harvested numerous similar collections from the same locality, but all of them matched the species *B. bainiugan* rather than *B. edulis* in our molecular analysis (Fig. 1). As the highly morphological similarity between *B. edulis* and *B. bainiugan* and actually it is difficult to separate them apart without DNA data, we strongly suggested that the name *B. edulis* is a misapplication for *B. bainiugan*.

Boletus griseus Frost (= *Retiboletus griseus* (Frost) Manfr. Binder & Bresinsky) is reported from Fenxi County of central Shanxi Province (Pan 2018). We are not able to examine this name-bearing specimen, but according to the pictures of basidioma, it is actually an infected *Suillellus* sp. According to our investigations, the *Suillellus* spp. is commonly encountered under oaks in the area nearby Fenxi County, and the infected frutibodies of *Suillelus* spp. by *Hypomyces* spp. are not uncommon.

Boletus queletii Schulzer (= *Suillellus queletii* (Schulzer) Vizzini, Simonini & Gelardi) is reported from the same locality as that of *B. griseus* (Pan 2018). The Pan's specimen is not available, but the pictures in Pan's book highly fits the species *Suillellus olivaceus*, a new species proposed in this study based on the specimens from the same locality. Thus, we convince that the name *Boletus queletii* used by Pan in his book is a misapplication. The European *B. queletii* (= *Suillellus queletii*) is actually not distributed in Shanxi Province.

Boletus regius Krombh. (= *Butyriboletus regius*) is reported from Heicha Mountain, Lvliang Mts. (Pan 2018). According to the pictures of basidioma, they are a typical *Villoboletus persicinus* because they have distinctly hairy stipe and pink pileus. We are not collected the European *Butyriboletus regius* in Shanxi Province, but its closely related species *Bu. sinoregius* is frequently encountered in southern Shanxi Province.

Leccinum aurantiacum is reported by Liu (1991) and Pan (2018). We have harvested some *L. aurantiacum*-like fruidbodies from several sites in Shanxi Province, and our molecular analysis based on a combined sequence dataset showed that they had the close affinity to *L. aurantiacum* (Fig. 1), but as the authentic sequence of this European species is still lacking, we consider it is better to define these collections as *Leccinum* cf. *aurantiacum* for the time being (Fig. 1).

Leccinum crocipodium (Letell.) Watling (= *Leccinellum crocipodium* (Letell.) Della Magg. & Trassin. Binder) is reported from northern Shanxi (Pan 2018). We are not able to check the Pan's

specimen, but according to the pictures of basidioma, we are sure it fits our concept of *Leccinum* cf. *scabrum* (Fig. 1). According to Bessette et al. (2017), *L. crocipodium* (= *Leccinellum crocipodium*) is probably a North American species with wrinkled, pitted, dark-brown to black-brown pileus, which is clearly different from the pictures in Pan's book.

Leccinum quercinum Pilát is reported from Wutai Mountain (Pan 2018). According to Index Fungorum, *L. quercinum* is a synonym of *Leccinum aurantiacum*. The pictures of basidioma for *Leccinum quercinum* in Pan's book actually well fits our concept of *Leccinum* cf. *scabrum* (Fig. 4i–l).

Leccinum rufum (Schaeff.) Kreisel is reported from Wutai Mountain (Pan 2018). According to Index Fungorum, *L. rufum* is a synonym of *Leccinum aurantiacum*. Actually, the picture of basidiomata in Pan'book for *L. rufum* is a typical *Suillus grevillei* (Klotzsch) Singer.

Leccinum scabrum is reported by Liu (1991) and Pan (2018). Our *L. scabrum*-like samples from several sites in Shanxi Province showed the close relationship to those sequences of "*L. scabrum*" downloaded from GenBank in our present molecular analysis (Fig. 1), however, the authentic sequence of this European species is still lacking, therefore, we treated these samples as *Leccinum* cf. *scabrum* for the time being (Fig. 1).

Tylopilus velatus (Rostr.) F.L. Tai (= *Veloporphyrellus velatus* (Rostr.) Yan C. Li & Zhu L. Yang) is reported from northern Shanxi Province (Pan 2018). According to the pictures of basidioma in Pan's book, it is a typical *Suillus viscidus* (L.) Roussel.

Xerocomus badius (Fr.) E.-J. Gilbert (= *Imleria badia* (Fr.) Vizzini) is reported from Wutai Mountain, northern Shanxi Province, under conifers (Liu 1991). The name-bearing specimen is lost according to the author, but the description by Liu (1991) well fits *Imleria badia*. We can't find this species in the same locality.

Xerocomus chrysenteron (Bull.) Quél. (= *Xerocomellus chrysenteron* (Bull.) Šutara) is reported from southern Shanxi Province, under oaks (Liu 1991). We are not able to examine the specimen of *X. chrysenteron*, but according to the description by Liu (1991), and the numerous newly harvested specimens in the same locality in this study, we are sure this name used by Liu (1991) is a misapplication. We introduced a new species *Hortiboletus rufosquamosus* according to our collections in this study (see Results).

Species diversity of Boletaceae in Shanxi Province of northern China

Currently, there are 25 Boletaceae species in this region, including 24 species supported by morphological and molecular data and one species (*Imleria badia*) supported only by morphology. Of the 24 species with DNA data, 13 species are introduced with Shanxi as their type locality, including *Butyriboletus brunneoides*, *Bu. sinoregius*, *Caloboletus griseoflavus*, *Cyanoboletus flavocontextus*, *Hortiboletus rufosquamosus*, *Ho. tomentosus*, *Neoboletus cinnamomeus*, *Retiboletus tingigriseus*, *Rubroboletus reticulatus*, *S. olivaceus*, *Villoboletus persicinus*, *Xerocomus galbanus* and *X. tenuistipitatus.* The remaining 11 species correspond to known species, including *Boletus bainiugan*, *Butyriboletus. parachinarensis*, *Chalciporus piperatus*, *Hemileccinum impolitum*, *Leccinum* cf. *aurantiacum*, *L.* cf. *scabrum*, *Strobilomyces strobilaceus*, *Suillellus subamygdalinus*, *Su. yunnanensis*, *Tylopilus himalayanus*, and *Xerocomus ferrugineus.*

Comparing with southwestern and southern China where more than hundred species of Boletaceae are recorded (Wu et al. 2014, 2016a), the species number and diversity of Boletaceae in Shanxi Province is relatively small. However, among the 25 recorded species, 13 species are with Shanxi as the type locality, accounting for more than 52%. This implies that the possibility of bolets of this region is relatively high as a native species, and suggests that the composition of species diversity in this region has distinct regional characteristics.

The geographic pattern and host association of Boletaceae species

Shanxi Province is located in the hinterland of northern China, ranging from 34° 34' N to 40° 44' N and 110° 14' E to 114° 33' E. It is mountainous, most areas of which have an altitude of more than 1000 meters. The climate ranges from subtropical to cold temperate. Climate types

significantly influence the distribution of Boletaceae species in this region. Our investigation reveals that most of the Boletaceae species prefer a warm climate. The examples that prefer both warm temperate and subtropical environments can be observed usually in central or southern areas in Shanxi Province, including *Boletus bainiugan*, *Caloboletus griseoflavus*, *Hortiboletus rufosquamosus*, *Neoboletus cinnamomeus*, *Retiboletus tingigriseus*, *Rubroboletus reticulatus*, *Suillellus olivaceus*, *Su. yunnanensis*, *Xerocomus ferrugineus* and *X. tenuistipitatus*. The examples that prefer warm temperate can be observed only in central regions, including *Butyriboletus parachinarensis* and *Villoboletus persicinus*. The examples that prefer subtropical environments can be observed only in southern regions, included *Butyriboletus brunneoides*, *Bu. sinoregius*, *Chalciporus piperatus*, *Cyanoboletus flavocontextus*, *Hemileccinum impolitum*, *Hortiboletus tomentosus*, *Strobilomyces strobilaceus*, *Tylopilus himalayanus* and *Xerocomus galbanus.* There are only two species in subalpine areas with cold temperate climate, i.e. *Imleria badia* and *Suillellus subamygdalinus*, both of the two species is observed only in northern region. *Leccinum* cf. *aurantiacum* and *L*. cf. *scabrum* are observed in all climate types in Shanxi Province. But their geographic distributions need further study because the delimitation of the two species is still unclear.

Most of the Boletaceae species in Shanxi Province are only associated with oaks (*Quercus* spp.), such as *Boletus bainiugan*, *Hortiboletus* spp., *Leccinum* cf. *aurantiacum*, *Suillellus* spp., and *Villoboletus persicinus*. *Suillellus subamygdalinus* is a rare example as it has been observed only under aspen (*Populus* sp.). *Leccinum* cf. *scabrum* is observed from birch (*Betula* spp.), Aspen (*Populus* sp.) and oaks (*Quercus* spp.) in Shanxi, and actually, the concept of *L.* cf. *scabrum* defined in this study may represent a species complex. The only species that had been observed in conifers (*Picea* sp. and *Pinus* sp.) is *Imleria badia* (Liu 1991), but we did not collect it again.

Acknowledgements

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Supplementary Table 1 Specimens used in four combined loci (ITS-nrLSU-*tef1*-*rpb2*) phylogenetic analysis and their GenBank accession numbers. Newly generated sequences are in bold.

Taxon	**Voucher ID**	**Country**	**ITS**	**nrLSU**	***tef1***	***rpb2***
Aureoboletus duplicatoporus	HKAS50498	China	–	KF112361	KF112230	KF112754
Aureoboletus erythraeus	FHMU3144	China	MT650100	MT650076	MT650114	–
Aureoboletus yunnanensis	HKAS75050	China	–	KT990520	KT990724	KT990361
Austroboletus fusisporus	HKAS75207	China	JX889719	JX889720	JX889718	–
Austroboletus occidentalis	MEL2300518	Australia	KC552017	KC552059	KC552100	–
Boletus aereus	REH8721	USA	–	KF030339	KF030426	–
Boletus bainiugan	**BJTC FM2253**	**China**	**OR655138**	**OR655177**	**OR659978**	**OR659929**
Boletus bainiugan	**BJTC FM2295**	**China**	**OR655139**	–	–	–
Boletus bainiugan	**BJTC FM2437**	**China**	**OR655141**	–	–	–
Boletus bainiugan	**BJTC FM2329**	**China**	**OR655140**	**OR655178**	**OR659979**	**OR659930**
Boletus edulis	BD298	USA	EU231985	EU232004	–	–
Boletus edulis	Trudell 03-289-09	USA	EU231983	EU232006	–	–
Boletus fagacicola	HKAS 83194	China	KM820789	KM820802	–	–
Boletus fagacicola	HKAS 83195	China	KM820790	KM820803	–	–
"*Boletus meiweiniuganjun*"	HKAS55393	China	JN563902	JN563852	–	–
Boletus monilifer	HKAS 83203	China	KM820791	KM820805	–	–
Boletus monilifer	HKAS 83205	China	KM820792	KM820806	–	–
Boletus monilifer	HKAS 83098	China	KM820793	KM820807	–	–
Boletus subalpinus	27882	USA	–	KF030340	KF030427	–
Boletus variipes	BD245	USA	EU231958	EU232003	–	–
Boletus viscidiceps	HKAS 83086	China	KM820797	KM820810	–	–
Boletus viscidiceps	HKAS 83138	China	KM820798	KM820811	–	–
Buchwaldoboletus lignicola	FLAS-F-58917	USA	MZ855279	–	MZ869815	MZ869820
Buchwaldoboletus lignicola	HKAS76674	China	–	KF112350	KF112277	KF112819
Butyriboletus brunneus	NY00013631	USA	KT002600	KT002611	KT002635	–
Butyriboletus brunneoides	**BJTC FM688**	**China**	**OR655142**	OL721648	OL799251	OL771222
Butyriboletus brunneoides	**BJTC FM1816**	**China**	**OR655143**	OL721747	OL799255	OL771223
Butyriboletus fechtneri	AT2003097	–	KC584784	KF030270	–	–
Butyriboletus parachinarensis	HKAS55413	China	–	KF112338	KF112157	KF112674

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Butyriboletus parachinarensis	**BJTC FM2769**	**China**	**OR655144**	**OR655179**	**OR659980**	**OR659931**
Butyriboletus parachinarensis	**BJTC FM2770**	**China**	–	**OR655180**	**OR659981**	**OR659932**
Butyriboletus parachinarensis	PC-43	Pakistan	MT825245	MT825244	–	–
Butyriboletus regius	KUN-HKAS 84878	Germany	–	MT264910	MT269659	MT269661
Butyriboletus regius	MG408a	–	KC584789	KC584790	–	–
Butyriboletus sanicibus	Arora99211	China	KC184469	KC184470	–	–
Butyriboletus sinoregius	BJTC FM755	China	OK490346	OL721748	OL799252	OL771224
Butyriboletus sinoregius	BJTC FM1103	China	–	OL721749	OL799253	OL771225
Butyriboletus sinoregius	BJTC FM1240	China	OK486135	OL721752	OL799254	OL771226
Butyriboletus subappendiculatus	MB000260	Germany	KT002607	KT002618	KT002642	–
Butyriboletus subappendiculatus	Wu 18328	Austria	JN903699	KC111201	–	–
Butyriboletus yicibus	HKAS68010	China	KJ909521	KT002619	KT002643	–
Butyriboletus yicibus	HKAS57503	China	KT002608	KT002620	KT002644	–
Butyriboletus yicibus	HKAS63528	China	–	KF112332	KF112156	KF112673
Caloboletus calopus	Bc1	Germany	DQ679806	AF456833	JQ327019	–
Caloboletus calopus	BR5020159063805	Belgium	KJ605655	KJ184554	KJ184566	–
Caloboletus firmus	MB06-060	USA	–	–	KF030408	–
Caloboletus firmus	NY00796115	Belize	KJ605656	KJ605678	KJ619464	–
Caloboletus griseoflavus	**BJTC FM699**	**China**	**OR655145**	**OR655181**	**OR659982**	**OR659933**
Caloboletus griseoflavus	**BJTC FM2221**	**China**	**OR655146**	**OR655182**	**OR659983**	**OR659934**
Caloboletus griseoflavus	**BJTC FM2438**	**China**	**OR655147**	**OR655183**	**OR659984**	**OR659935**
Caloboletus guanyui	FHMU 2019	China	MH885365	MH879708	MH879734	MH879751
Caloboletus guanyui	FHMU 2040	China	MH885366	MH879709	MH879736	MH879752
Caloboletus inedulis	MB06-044	USA	–	JQ327013	JQ327020	–
Caloboletus inedulis	HKAS80478	USA	KJ605657	KJ605671	KJ619465	–
Caloboletus panniformis	HKAS57410	China	KJ605659	KJ184555	KJ184567	–
Caloboletus panniformis	HKAS77530	China	KJ605661	KJ605670	KJ619470	–
Caloboletus polygonius	K(M)60247	Greece	KU317753	KU317763	–	–
Caloboletus radicans	HKAS80856	France	KJ605662	KJ184557	KJ184569	–
Caloboletus taienus	GDGM44081	China	KY800420	KY800414	–	–

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Caloboletus xiangtoushanensis	GDGM44833	China	KY800421	KY800415	KY800418	–
Caloboletus xiangtoushanensis	GDGM45160	China	KY800423	KY800417	KY800419	–
Caloboletus yunnanensis	HKAS69214	China	KJ605663	KJ184556	KJ184568	–
Caloboletus yunnanensis	HKAS58694	China	KJ605664	KJ605672	KJ619470	–
Chalciporus piperatus	K80S25b	New Zealand	GQ267470	–	–	–
Chalciporus piperatus	NAMPA2206-22	USA	OP225584	–	–	–
Chalciporus piperatus	**BJTC FM2220**	**China**	**OR655148**	**OR655184**	**OR659985**	**OR659936**
Chalciporus pseudorubinellus	4302	USA	–	KF030284	KF030441	–
Chalciporus radiatus	GDGM50080	China	KP871806	KP871801	MZ165611	–
Chalciporus radiatus	GDGM43285	China	KP871804	KP871800	MZ165610	–
Chalciporus rubinelloides	HKAS74952	China	–	KT990565	KT990761	KT990400
Chalciporus rubinelloides	HKAS58728	China	–	KT990564	KT990760	KT990399
Chalciporus vulparius	FHMU5554	China	–	MW917173	MW925930	MW925936
Chalciporus vulparius	FHMU5560	China	–	MW917174	MW925931	MW925937
Chiua olivaceoreticulata	HKAS59706	China	–	KT990593	KT990787	KT990428
Crocinoboletus laetissimus	FHMU2030	China	MK850940	MK850935	MK850948	MK850944
Crocinoboletus rufoaureus	HKAS53424	China	MW520199	KF112435	KF112206	KF112710
Crocinoboletus rufoaureus	FHMU1975	China	MK850937	MK850931	MK850947	MK850942
Cyanoboletus bessettei	ARB 1393A	USA	MW675737	MW662571	MW737482	MW737457
Cyanoboletus bessettei	ARB 1393B	USA	MW675738	–	MW737483	MW737458
Cyanoboletus brunneoruber	HKAS 63504	China	–	KF112368	KF112194	–
Cyanoboletus brunneoruber	HKAS 80579-1	China	–	KT990568	KT990763	–
Cyanoboletus cyaneitinctus	JAB_324	–	MW675732	MW662586	–	MW737469
Cyanoboletus cyaneitinctus	JAB_325	–	MW675733	–	–	MW737470
Cyanoboletus fagaceophilus	HKAS 123872	China	–	OQ888717	OQ873454	OQ873493
Cyanoboletus fagaceophilus	HKAS 126556	China	OQ888702	OQ888718	OQ873455	OQ873494
Cyanoboletus fagaceophilus	HKAS 80691	China	–	OQ888719	OQ873456	OQ873495
Cyanoboletus flavocontextus	**BJTC FM2319-A**	**China**	**OR655149**	**OR655185**	**OR659986**	**OR659937**
Cyanoboletus flavocontextus	**BJTC FM2319-B**	**China**	–	**OR655226**	**OR660025**	**OR659976**
Cyanoboletus hymenoglutinosus	DC14-010	India	KT907355	KT860060	–	–

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Cyanoboletus instabilis	HKAS59554	China	–	KF112412	KF112186	–
Cyanoboletus instabilis	FHMU1839	China	MG030473	MG030466	MG030478	–
Cyanoboletus pulverulentus	MICH:KUO-09220408	USA	–	MK601732	MK721086	MK766294
Cyanoboletus pulverulentus	9606	USA	–	KF030313	KF030418	–
Cyanoboletus pulverulentus	MG 628a	Italy	–	KT157064	KT157073	KT157069
Cyanoboletus pulverulentus	MG126a	Italy	KT157053	KT157062	–	–
Cyanoboletus sinopulverulentus	HKAS59609	China	–	KF112366	KF112193	–
Cyanoboletus sp.	HKAS52639	China	–	KF112367	KF112195	–
Cyanoboletus sp.	HKAS59418	China	–	KT990570	KT990765	–
Cyanoboletus sp.	HKAS90208-1	China	–	KT990571	KT990766	–
Cyanoboletus sp.	HKAS90208-2	China	–	–	KT990767	–
Cyanoboletus sp.	HKAS76850	China	–	KF112343	KF112187	–
Gyrodon lividus	REG Gl1	Germany	DQ534568	–	GU187701	GU187786
Gyrodon sp.	HKAS57588	China	–	KF112348	KF112275	KF112817
Gyrodon sp.	HKAS59448	China	–	KF112349	KF112276	KF112818
Gyrodon sp.	HKAS63505	China	–	KF112476	KF112310	KF112826
Gyrodon sp.	HKAS52520	China	–	KF112475	KF112309	KF112825
Gyroporus castaneus	HKAS76672	China	–	KF112478	KF112311	KF112827
Harrya atrogrisea	HKAS50542	China	–	KT990694	KT990880	KT990499
Harrya subalpina	HKAS50546	China	–	KT990692	KT990879	MT110450
Heimioporus japonicus	HKAS52237	China	–	KF112347	KF112228	KF112806
Heimioporus subretisporus	HKAS80581	China	–	KT990573	KT990769	KT990407
Hemileccinum albidum	HKAS50503	China	MZ923781	MZ923767	MZ936355	MZ936319
Hemileccinum albidum	HKAS50350	China	MZ923779	MZ923768	MZ936359	MZ936323
Hemileccinum brevisporum	HKAS89150	China	MZ923788	MZ923764	MZ936362	MZ936328
Hemileccinum brevisporum	HKAS59445	China	–	KT990579	KT990775	KT990414
Hemileccinum depilatum	AF2845	Belgium	–	–	MG212591	MG212633
Hemileccinum impolitum	HKAS 84869	Germany	–	KT990575	KT990771	–
Hemileccinum impolitum	Bim1	Germany	–	AF139715	JQ327034	–
Hemileccinum impolitum	**BJTC FM696**	**China**	**OR655150**	**OR655186**	**OR659987**	**OR659938**

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Hortiboletus aff. *rubellus*	MB03033	USA	–	KF030294	KF030419	–
Hortiboletus amygdalinus	HKAS54166	China	–	KT990581	KT990777	–
Hortiboletus amygdalinus	HKAS54242	China	–	KT990580	KT990776	–
Hortiboletus arduinus	FHMU3323	China	–	MT646432	MT646447	–
Hortiboletus arduinus	FHMU3324	China	–	MT646439	MT646448	–
Hortiboletus indorubellus	DC 14002	India	KT319647	–	–	–
Hortiboletus indorubellus	LS15	Pakistan	MK002767	MK002872	–	–
Hortiboletus kohistanensis	LAH35285	Pakistan	MG988193	–	–	–
Hortiboletus kohistanensis	LAH35327	Pakistan	MG988192	MG988187	–	–
Hortiboletus napaeus	FHMU3325	China	MT646445	MT646438	MT646449	–
Hortiboletus napaeus	FHMU3326	China	MT646440	MT646433	MT646450	–
Hortiboletus rubellus	LAH35030	Pakistan	KX907539	–	–	–
Hortiboletus rubellus	FLAS-F-61506	USA	MH211937	–	–	–
Hortiboletus rubellus	FLAS-F-60315	USA	MF153033	–	–	–
Hortiboletus rubellus	FLAS-F-60513	USA	MH211664	–	–	–
Hortiboletus rubellus	52A	Spain	MN652008	–	–	–
Hortiboletus rufosquamosus	**BJTC FM2649**	**China**	**OR655151**	**OR655187**	**OR659988**	**OR659939**
Hortiboletus rufosquamosus	**BJTC FM2652**	**China**	**OR655152**	**OR655188**	**OR659989**	**OR659940**
Hortiboletus rufosquamosus	**BJTC FM2660**	**China**	**OR655153**	**OR655189**	**OR659990**	**OR659941**
Hortiboletus rufosquamosus	**BJTC FM2680**	**China**	**OR655154**	**OR655190**	**OR659991**	**OR659942**
Hortiboletus rufosquamosus	**BJTC FM2687**	**China**	**OR655155**	**OR655191**	**OR659992**	**OR659943**
Hortiboletus rufosquamosus	**BJTC FM2692**	**China**	**OR655156**	**OR655192**	**OR659993**	**OR659944**
Hortiboletus sp.	FHMU2113	China	MT646444	MT646437	MT646446	–
Hortiboletus sp.	DD614	USA	MH168538	MH203598	–	–
Hortiboletus sp.	JLF6662	USA	MN306135	MN294425	–	–
Hortiboletus sp.	JLF6654	USA	MN306134	MN294424	–	–
Hortiboletus sp.	HKAS50466	China	–	KF112372	KF112183	–
Hortiboletus sp.	HKAS51292	China	–	KF112369	KF112181	–
Hortiboletus subpaludosus	HKAS52659	China	–	KT990582	KT990778	–
Hortiboletus subpaludosus	HKAS59608	China	–	KF112371	KF112185	–

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Hortiboletus subpaludosus	HKAS68158	China	–	KT990583	KT990779	–
Hortiboletus tomentosus	**BJTC FM2289-A**	**China**	–	**OR655193**	**OR659994**	**OR659945**
Hortiboletus tomentosus	**BJTC FM2289-B**	**China**	–	**OR655227**	**OR660026**	**OR659977**
Hymenoboletus luteopurpureus	HKAS46334	China	–	KF112471	KF112271	KF112795
Imleria badia	HKAS74714	China	–	KC215212	KC215242	–
Imleria obscurebrunnea	HKAS52557	China	KC215207	KC215220	KC215243	KC215234
Imleria subalpina	HKAS74712	China	KC215208	KC215218	KC215246	KC215239
Lanmaoa angustispora	HKAS74759	China	–	KM605140	KM605155	KM605178
Lanmaoa asiatica	HKAS63516	China	–	KT990584	KT990780	KT990419
Lanmaoa pseudosensibilis	DS615-07	USA	–	KF030257	KF030407	–
Leccinum album	KUN-HKAS53417	China	MZ392872	MW413907	MW439267	MW439259
Leccinum album	KUN-HKAS53417	China	MZ392873	–	HQ326861	MW439260
Leccinum aurantiacum	L-0342207	France	–	MK601759	MK721113	MK766318
Leccinum cerinum	MK11800	Finland	–	AF139692	–	–
Leccinum* cf. *aurantiacum	**BJTC FM2191**	**China**	–	**OR655198**	**OR659998**	**OR659950**
Leccinum* cf. *aurantiacum	**BJTC FM2419**	**China**	–	**OR655199**	**OR659999**	**OR659951**
Leccinum* cf. *scabrum	**BJTC FM1462**	**China**	–	**OR655194**	**OR659995**	**OR659946**
Leccinum* cf. *scabrum	**BJTC FM1923**	**China**	–	**OR655195**	**OR659996**	**OR659947**
Leccinum* cf. *scabrum	**BJTC FM2336**	**China**	–	**OR655196**	**OR659997**	**OR659948**
Leccinum* cf. *scabrum	**BJTC FM817**	**China**	–	**OR655197**	–	**OR659949**
Leccinum duriusculum	KUN-HKAS101160	Uzbekistan	MZ485402	MZ675541	MZ707785	MZ707779
Leccinum duriusculum	GL4676	France	–	AF139699	–	–
Leccinum holopus	MICH:KUO09150707	USA	–	MK601763	MK721117	MK766322
Leccinum holopus	KUN-HKAS111906	Austria	–	MW413906	MW439266	MW439258
Leccinum manzanitae	NY-14041	USA	–	MK601765	MK721119	MK766324
Leccinum melaneum	KUN-HKAS57220	China	MZ485409	MZ675542	MZ707786	MZ707780
Leccinum monticola	NY-00815448	Costa Rica	–	MK601767	MK721121	MK766326
Leccinum monticola	NY-760388	Costa Rica	–	MK601766	MK721120	MK766325
Leccinum monticola	NY-760388	Costa Rica	–	MK601766	–	MK766325
Leccinum pallidocastaneum	KUN-HKAS52538	China	ON858185	ON858189	ON855010	KF112721

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Leccinum pallidocastaneum	KUN-HKAS52553	China	ON858186	ON858190	ON855011	ON855014
Leccinum palustre	MK11107	Germany	–	AF139701	–	–
Leccinum parascabrum	KUN-HKAS99903	China	MZ392874	MW413911	MW439271	MW439264
Leccinum parascabrum	KUN-HKAS59447	China	MZ392875	MW413912	MW439272	MW439265
Leccinum phaeocarpum	KUN-HKAS115851	China	ON858187	ON858192	ON855012	ON855015
Leccinum phaeocarpum	KUN-HKAS93967	China	ON858188	ON858193	ON855013	ON855016
Leccinum pseudoborneense	KUN-HKAS110156	China	MZ412902	MW413908	MW439268	MW439261
Leccinum pseudoborneense	KUN-HKAS110157	China	MZ412903	MW413909	MW439269	MW439262
Leccinum pseudoborneense	KUN-HKAS110158	China	MZ412904	MW413910	MW439270	MW439263
"Leccinum quercinum"	KUN-HKAS63502	China	–	–	KF112250	KF112724
Leccinum scabrum	KUN-HKAS56371	China	–	KT990587	KT990782	KT990423
Leccinum schistophilum	KUN-HKAS98024	China	MZ503508	MZ675544	MZ707788	–
Leccinum schistophilum	VDKO1128	Belgium	–	–	KT824055	KT824022
Leccinum subradicatum	KPM-NC-24518	Japan	MT934814	MT812736	MT874822	–
Leccinum versipelle	KUN-HKAS97997	China	MZ485404	MZ675545	MZ707789	MZ707781
Leccinum versipelle	KUN-HKAS99380	China	MZ485401	MZ675546	MZ707790	MZ707782
Mucilopilus castaneiceps	HKAS75045	China	–	KF112382	KF112211	KF112735
Neoboletus brunneissimus	HKAS52660	China	–	KF112314	KF112143	KF112650
Neoboletus brunneorubrocarpus	HKAS 126559	China	–	OQ888720	OQ873457	OQ873496
Neoboletus brunneorubrocarpus	HKAS 76660	China	OQ888703	KF112328	KF112180	KF112731
Neoboletus cinnamomeus	**BJTC FM1055**	**China**	**OR655157**	**OR655200**	–	**OR659952**
Neoboletus ferrugineus	HKAS77617	China	–	KT990595	KT990788	KT990430
Neoboletus ferrugineus	HKAS77718	China	–	KT990596	KT990789	KT990431
Neoboletus flavidus	HKAS58724	China	–	KU974140	KU974137	KU974145
Neoboletus flavidus	HKAS59443	China	–	KU974139	KU974136	KU974144
Neoboletus hainanensis	HKAS59469	China	–	KF112359	KF112175	KF112669
Neoboletus hainanensis	HKAS90209	China	–	KT990615	KT990809	KT990450
Neoboletus hainanensis	HKAS63515	China	–	KT990614	KT990808	KT990449
Neoboletus luridiformis	AT2001087	England	–	JQ326995	JQ327023	–
Neoboletus magnificus	HKAS54096	China	–	KF112324	KF112149	KF112654

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Neoboletus magnificus	HKAS74939	China	–	KF112320	KF112148	KF112653
Neoboletus multipunctatus	FHMU 1620	China	MH885354	MH879693	MH879722	–
Neoboletus multipunctatus	FHMU 2808	China	MK061359	MK061360	MK061358	–
Neoboletus obscureumbrinus	FHMU 2052	China	MH885355	MH879694	MH879723	MH879742
Neoboletus obscureumbrinus	FHMU 2055	China	MH885356	MH879695	MH879724	MH879743
Neoboletus obscureumbrinus	FHMU 2059	China	MH885357	MH879696	MH879725	MH879744
Neoboletus rubriporus	HKAS83026	China	–	KT990601	KT990795	KT990437
Neoboletus rubriporus	HKAS89174	China	–	KT990602	KT990796	KT990438
Neoboletus rubriporus	HKAS90210	China	–	KT990604	KT990798	KT990439
Neoboletus sanguineoides	HKAS55440	China	–	KF112315	KF112145	KF112652
Neoboletus sanguineoides	HKAS57766	China	–	KT990605	KT990799	KT990440
Neoboletus sanguineoides	HKAS80823	China	–	KT990605	KT990799	KT990440
Neoboletus sanguineus	HKAS80849	China	–	KT990609	KT990803	KT990443
Neoboletus sanguineus	HKAS90211	China	–	KT990610	KT990804	KT990444
Neoboletus sanguineus	HKAS68587	China	–	KF112329	KF112150	KF112657
Neoboletus thibetanus	HKAS57093	China	–	KF112326	–	KF112655
Neoboletus tomentulosus	FHMU 841	China	MH885352	MH879691	MH879720	–
Neoboletus tomentulosus	FHMU 842	China	MH885353	MH879692	MH879721	–
Neoboletus venenatus	HKAS57489	China	–	KF112325	KF112158	KF112665
Neoboletus venenatus	HKAS63535	China	–	KT990613	KT990807	KT990448
Paragyrodon sphaerosporus	MB06-066	USA	GU187540	GU187593	GU187737	GU187803
Paxillus filamentosus	Pf1	Germany	–	AF167680	GU187736	–
Paxillus obscurosporus	Po1	Germany	–	–	KF030442	–
Paxillus vernalis	AFTOL-ID 715	China	DQ647827	AY645059	DQ457629	–
Porphyrellus castaneus	HKAS63076	China	–	KT990548	KT990749	KT990386
Porphyrellus castaneus	HKAS52554	China	–	KT990697	–	KT990502
Porphyrellus orientifumosipes	HKAS53372	China	–	KT990629	KT990823	KT990461
Porphyrellus orientifumosipes	HKAS75078	China	–	KF112481	KF112242	KF112717
Porphyrellus porphyrosporus	HKAS49182	China	–	KT990544	–	KT990383
Porphyrellus porphyrosporus	HKAS76671	China	–	KF112482	KF112243	KF112718

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Retiboletus ater	Li1215	China	–	MT010611	MT010621	–
Retiboletus ater	Li1224	China	–	MT010612	MT010622	–
Retiboletus brevibasidiatus	OR0570	Thailand	–	–	MT085476	MT085479
Retiboletus brunneolus	HKAS106427	China	OM904974	OM904940	MT110362	–
Retiboletus brunneolus	HKAS77764	China	OM904975	OM904941	–	–
Retiboletus cyanescens	HKAS 122939	China	OM904976	OM904954	ON055267	–
Retiboletus cyanescens	HKAS 122940	China	OM904977	OM904957	ON055268	ON004082
Retiboletus cyanescens	HKAS 106692	China	OM904978	OM904956	ON055270	ON004083
Retiboletus fuscus	Wu445	China	–	KT990636	KT990830	–
Retiboletus fuscus	Cui47	China	–	MT010614	MT010624	–
Retiboletus griseus	snBoth	USA	–	KF030308	KF030414	–
Retiboletus griseus	Halling10162	USA	–	MT010608	MT010618	–
Retiboletus kauffmanii	G.Wu352	China	–	–	KP739301	KP739299
Retiboletus kauffmanii	HKAS63584	China	–	–	KT990828	KT990465
Retiboletus nigerrimus	Tyni1	Japan	–	AF456832	–	–
Retiboletus nigrogriseus	FHMU2045	China	–	MH367475	MH367487	–
Retiboletus nigrogriseus	FHMU2800	China	–	MH367476	MH367488	–
Retiboletus ornatipes	201/97	USA	–	AF456815	–	–
Retiboletus ornatipes	Halling10163	USA	–	MT010617	MT010626	–
Retiboletus pseudogriseus	Zeng647	China	–	MT010613	MT010623	–
Retiboletus pseudogriseus	FHMU375	China	–	MH367477	MH367489	–
Retiboletus retipes	96/97	USA	–	AF456830	–	–
Retiboletus retipes	22/97	USA	–	AF456831	–	–
Retiboletus sinensis	HKAS83955	China	KP739272	KP739289	KP739302	–
Retiboletus sinensis	HKAS59832	China	–	KT990633	KT990827	KT990464
Retiboletus sinensis	HKAS122943	China	OM904988	OM904950	–	ON004086
Retiboletus sinogriseus	LJ260	China	–	MT010609	MT010619	–
Retiboletus sinogriseus	LJ258	China	–	MT010610	MT010620	–
Retiboletus tingigriseus	**BJTC FM1736**	**China**	–	**OR655201**	**OR660000**	**OR659953**
Retiboletus tingigriseus	**BJTC FM1797**	**China**	**OR655158**	**OR655202**	**OR660001**	**OR659954**

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Retiboletus tingigriseus	**BJTC FM2269**	**China**	–	**OR655203**	**OR660002**	**OR659955**
Retiboletus vinaceipes	CFMR DR-1035	–	MN250205	MN250180	–	–
Retiboletus vinaceipes	CFMR:BZ-2386	Belize	MN250217	MN250190	–	–
Retiboletus zhangfeii	HKAS83962	China	NR_154413	NG_059552	KP739306	–
Retiboletus zhangfeii	HKAS53420	China	OM904964	OM904952	MT110360	–
Rossbeevera bispora	GDGM 46631	China	MK035706	MK036348	–	–
Rossbeevera cryptocyanea	KPM-NC 26877	Japan	MT934783	MT812703	MT874787	–
Rossbeevera eucyanea	KPM-NC 28182	Japan	MT934782	MT812702	MT874786	–
Royoungia boletoides	REH8851	Australia	–	JX889678	JX889710	–
Royoungia reticulata	HKAS52253	China	–	KT990592	KT990786	KT990427
Rubroboletus dupainii	JAM0607	USA	–	KF030251	KF030413	–
Rubroboletus esculentus	K.Zhao893	China	KY272125	KY272129	KY272138	KY272135
Rubroboletus esculentus	Hui M.Shao-F1	China	KY272126	KY272130	KY272139	KY272136
Rubroboletus flammeus	FHMU6927	China	–	OM514334	OM525826	OM525824
Rubroboletus flavus	HKAS 126558	China	–	OQ888721	OQ873458	–
Rubroboletus flavus	HKAS 90906	China	OQ888704	OQ888722	OQ873459	OQ873497
Rubroboletus latisporus	HKAS 80358	China	KJ951990	KP055023	KP055020	KP055029
Rubroboletus latisporus	HKAS 63517	China	KJ951989	KP055022	KP055019	KP055028
Rubroboletus legaliae	PRM 921886	Slovakia	LT797161	LT797167	LT797168	–
Rubroboletus legaliae	MB-000295	Germany	KY272124	KY272128	KY272137	KY272134
Rubroboletus reticulatus	**BJTC FM1077**	**China**	**OR655159**	**OR655204**	**OR660003**	**OR659956**
Rubroboletus reticulatus	**BJTC FM1784**	**China**	**OR655160**	**OR655205**	**OR660004**	**OR659957**
Rubroboletus reticulatus	**BJTC FM1812**	**China**	**OR655161**	**OR655206**	**OR660005**	**OR659958**
Rubroboletus rhodoxanthus	HKAS84879	Germany	–	KT990637	KT990831	KT990468
Rubroboletus serpentiformis	HKAS 126557	China	OQ888705	OQ888723	OQ873460	OQ873498
Rubroboletus serpentiformis	HKAS 126547	China	–	OQ888724	OQ873461	OQ873499
Rubroboletus sinicus	HKAS68620	China	MW520195	KY418896	KF112146	KF112661
Rubroboletus sinicus	HKAS56304	China	KJ605666	KJ605673	KJ619483	KP055031
Strobilomyces echinocephalus	HKAS59420	China	MG832059	–	KX869274	KX869400
Strobilomyces echinocephalus	HKAS75765	China	MG832060	–	KX869273	KX869399

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Strobilomyces mirandus	HKAS80364	China	MG832071	–	–	KX869420
Strobilomyces mirandus	HKAS59408	China	MG832070	–	KX869293	KX869419
Strobilomyces pteroreticulosporus	HKAS80350	China	MG832075	–	KX869303	KX869430
Strobilomyces pteroreticulosporus	HKAS80299	China	MG832076	–	KX869304	KX869431
Strobilomyces strobilaceus	HKAS75466	China	–	KT990644	KT990836	KT990473
Strobilomyces strobilaceus	**BJTC FM687**	**China**	**OR655162**	**OR655207**	**OR660006**	**OR659959**
Strobilomyces strobilaceus	**BJTC FM1059**	**China**	**OR655163**	**OR655208**	**OR660007**	**OR659960**
Suillellus amygdalinus	112605ba	USA	–	JQ326996	JQ327024	–
Suillellus comptus	AMB 12639	Italy	KC734539	–	–	–
Suillellus comptus	17827	Italy	JF907791	–	–	–
Suillellus flaviporus	HKAS 123826	China	OQ888706	OQ888726	OQ873463	OQ873501
Suillellus flaviporus	HKAS 126554	China	–	OQ888727	OQ873464	OQ873502
Suillellus flaviporus	HKAS 126555	China	–	OQ888728	OQ873465	OQ873503
Suillellus lacrymibasidiatus	HMJAU60202	China	OM237315	OM230174	OM285117	OM285115
Suillellus lacrymibasidiatus	HMJAU60203	China	OM237338	OM230172	OM285116	OM285114
Suillellus luridus	AMB 12636	Italy	KC734542	–	–	–
Suillellus luridus	AMB 12638	Italy	KC734544	–	–	–
Suillellus mendax	AMB 12633	Italy	KC734548	–	–	–
Suillellus mendax	AMB 12634	Italy	KC734543	–	–	–
Suillellus olivaceus	**BJTC FM1755**	**China**	**OR655167**	**OR655212**	**OR660011**	**OR659964**
Suillellus olivaceus	**BJTC FM1765**	**China**	**OR655168**	**OR655213**	**OR660012**	**OR659965**
Suillellus olivaceus	**BJTC FM2411**	**China**	–	**OR655214**	**OR660013**	–
Suillellus pinophilus	HKAS 126550	China	OQ888707	OQ888729	OQ873466	OQ873504
Suillellus subamygdalinus	HKAS57262	China	–	KF112316	KF112174	KF112660
Suillellus subamygdalinus	HKAS53641	China	–	KT990651	KT990841	KT990478
Suillellus subamygdalinus	HKAS57953	China	–	KT990652	KT990842	–
Suillellus subamygdalinus	HKAS74745	China	–	KT990653	KT990843	KT990479
Suillellus subamygdalinus	**BJTC FM2576**	**China**	**OR655169**	**OR655215**	**OR660014**	**OR659966**
Suillellus yunnanensis	HKAS 126548	China	OQ888708	OQ888730	OQ873467	OQ873505
Suillellus yunnanensis	HKAS 126549	China	–	OQ888731	OQ873468	OQ873506

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Suillellus yunnanensis	**BJTC FM1064**	**China**	**OR655164**	**OR655209**	**OR660008**	**OR659961**
Suillellus yunnanensis	**BJTC FM1814**	**China**	**OR655165**	**OR655210**	**OR660009**	**OR659962**
Suillellus yunnanensis	**BJTC FM2334**	**China**	**OR655166**	**OR655211**	**OR660010**	**OR659963**
Suillus aff. *granulatus*	HKAS 57622	China	–	KF112429	KF112280	KF112797
Suillus aff. *luteus*	HKAS 57748	China	–	KF112430	KF112281	KF112824
Tengioboletus glutinosus	HKAS53452	China	–	KT990655	KT990844	KT990480
Tengioboletus glutinosus	HKAS53425	China	–	KF112341	KF112204	KF112800
Tengioboletus reticulatus	HKAS53453	China	–	KT990656	KT990846	KT990482
Tengioboletus reticulatus	HKAS53426	China	–	KF112491	KF112313	KF112828
Turmalinea chrysocarpa	HKAS70601	China	KC552003	KC552051	–	–
Turmalinea mesomorpha	KPM-NC-0018015	Japan	KC552001	KC552049	KC552092	–
Turmalinea persicina	KPM-NC-0018001	Japan	KC551991	KC552038	KC552082	–
Tylopilus alpinus	HKAS55438	China	–	KF112404	KF112191	KF112687
Tylopilus felleus	HKAS54926	China	–	KF112411	–	KF112737
Tylopilus felleus	HKAS90203	China	–	KT990545	–	KT990384
Tylopilus himalayanus	DC 17-31	India	MG799323	MG799326	–	–
Tylopilus himalayanus	DC 17-25	India	MG799322	MG799328	–	–
Tylopilus himalayanus	**BJTC FM2315**	**China**	**OR655170**	**OR655216**	**OR660015**	**OR659967**
Tylopilus microsporus	HKAS59661	China	–	KF112450	KF112225	KF112798
Tylopilus otsuensis	HKAS53401	China	–	KF112449	KF112224	KF112797
Tylopilus plumbeoviolaceoides	HKAS50210	China	–	KF112431	KF112221	KF112738
Veloporphyrellus alpinus	HKAS57490	China	–	JX984537	JX984549	–
Villoboletus persicinus	**BJTC FM1869**	**China**	**OR655135**	OP793898	OP792035	OP792032
Villoboletus persicinus	**BJTC FM1904**	**China**	**OR655136**	OP793899	OP792036	OP792033
Villoboletus persicinus	**BJTC FM1906**	**China**	**OR655137**	OP793900	OP792037	OP792034
Xanthoconium porophyllum	GDGM 30303	–	KC168089	KC561775	–	–
Xanthoconium porophyllum	HKAS90217	China	–	KT990662	–	KT990487
Xanthoconium purpureum	NY00720964	USA	–	KT990663	KT990852	–
Xanthoconium sinense	HKAS77758	China	–	KT990665	KT990854	KT990489
Xanthoconium sinense	HKAS77651	China	–	KT990664	KT990853	KT990488

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Xerocomellus chrysenteron	HKAS56494	China	–	KF112357	KF112172	KF112685
Xerocomellus cisalpinus	PDD94421	New Zealand	JQ924296	JQ924322	KF112171	KF112686
Xerocomellus communis	HKAS 50467	China	–	KT990670	KT990858	KT990494
Xerocomellus communis	HKAS68204	China	–	KT990671	KT990859	KT990495
Xerocomellus corneri	HKAS52503	China	–	KT990668	KT990856	KT990492
Xerocomellus corneri	HKAS90206	China	–	KT990669	KT990857	KT990493
Xerocomus ferrugineus	MICH KUO-08100701	USA	–	MK601820	MK721174	–
Xerocomus ferrugineus	CFMR BOS-545	USA	–	MK601819	MK721173	–
Xerocomus ferrugineus	AH2000024	–	DQ066396	–	–	–
Xerocomus ferrugineus	AH2000108	–	DQ066400	–	–	–
Xerocomus ferrugineus	**BJTC FM1245**	**China**	**OR655173**	**OR655219**	**OR660018**	–
Xerocomus ferrugineus	**BJTC FM1248**	**China**	**OR655174**	**OR655220**	**OR660019**	**OR659970**
Xerocomus ferrugineus	**BJTC FM2186**	**China**	**OR655175**	**OR655221**	**OR660020**	**OR659971**
Xerocomus ferrugineus	**BJTC FM2369**	**China**	**OR655176**	**OR655222**	**OR660021**	**OR659972**
Xerocomus ferrugineus	**BJTC FM1845**	**China**	–	**OR655225**	**OR660024**	**OR659975**
Xerocomus fraternus	HKAS52526	China	–	KT990682	KT990870	–
Xerocomus fraternus	HKAS55328	China	–	KT990681	KT990869	KT990497
Xerocomus fulvipes	HKAS52556	China	–	KT990672	KT990860	–
Xerocomus galbanus	**BJTC FM1790**	**China**	**OR655171**	**OR655217**	**OR660016**	**OR659968**
Xerocomus galbanus	**BJTC FM1813**	**China**	**OR655172**	**OR655218**	**OR660017**	**OR659969**
Xerocomus magniporus	HKAS:59820	China	JQ678697	JQ678699	JQ967195	JQ678701
Xerocomus magniporus	HKAS58000	China	–	KF112392	KF112293	KF112781
Xerocomus microcapoides	HKAS53374	China	–	KT990679	KT990867	–
Xerocomus microcapoides	HKAS54753	China	–	KT990680	KT990868	–
Xerocomus perplexus	MB00-005	USA	–	JQ003702	KF030438	–
Xerocomus piceicola	HKAS55452	China	–	KT990685	–	–
Xerocomus piceicola	HKAS76492	China	–	KT990684	KT990872	–
Xerocomus puniceiporus	HKAS80683	China	–	KU974141	KU974138	KU974146
Xerocomus rugosellus	HKAS58865	China	–	KF112389	KF112294	KF112784
Xerocomus rugosellus	HKAS68292	China	–	KT990686	KT990873	–

Supplementary Table 1 Continued.

Taxon	Voucher ID	Country	ITS	nrLSU	*tef1*	*rpb2*
Xerocomus sp.	HKAS75076	China	–	KF112387	KF112290	KF112778
Xerocomus sp.	HKAS74927	China	–	KF112395	KF112291	KF112779
Xerocomus sp.	HKAS76853	China	–	KF112394	KF112296	KF112783
Xerocomus sp.	HKAS57339	China	–	KT990674	KT990862	–
Xerocomus sp.	HKAS57765	China	–	KT990675	KT990863	–
Xerocomus sp.	HKAS67749	China	–	KT990676	KT990864	–
Xerocomus sp.	HKAS90207	China	–	KT990677	KT990865	–
Xerocomus subparvus	HKAS53387	China	–	KF112397	KF112297	KF112788
Xerocomus subparvus	HKAS82184	China	–	KT990678	KT990866	KT990496
Xerocomus subtomentosus	KM167686	UK	KC215201	KC215222	KC215248	–
Xerocomus subtomentosus	KM168813	UK	KC215200	KC215223	KC215249	–
Xerocomus tenuistipitatus	**BJTC FM2267**	**China**	–	**OR655223**	**OR660022**	**OR659973**
Xerocomus tenuistipitatus	**BJTC FM2684**	**China**	–	**OR655224**	**OR660023**	**OR659974**
Xerocomus velutinus	HKAS52575	China	–	KF112393	KF112295	KF112782
Xerocomus velutinus	HKAS68135	China	–	KT990673	KT990861	–
Xerocomus yunnanensis	HKAS68282	China	–	KT990691	KT990878	–
Xerocomus yunnanensis	HKAS68420	China	–	KT990690	KT990877	–
Zangia citrina	HKAS52677	China	–	HQ326940	HQ326871	–
Zangia olivacea	HKAS55830	China	–	HQ326946	HQ326874	–
Zangia roseola	HKAS52661	China	JQ928614	JQ928623	JQ928584	JQ928604